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Teacher Perceptions of the Impact of Vertical Non-Permanent Surfaces in Mathematics Classrooms

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TEACHER PERCEPTIONS OF THE IMPACT OF VERTICAL NON-PERMANENT SURFACES IN MATHEMATICS CLASSROOMS

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Dedication

The dedication of this dissertation is to all the mathematics teachers who constantly try to find the best ways to teach for student learning. You are encouraged to continuously take risks and experiment with new instructional ideas to assist students with understanding the world of mathematics. You are my heroes! I would like to acknowledge my family, friends, and colleagues who continued to inspire me and support me in completing this degree.

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Abstract

The historical, traditional mathematics classroom of students sitting in rows receiving information from the teacher and working individually was still prevalent in the 21st century. Many teachers had resorted to student-centered activities to engage passive students, but the minimal progress of math achievement of United States students denoted a need for the reform of the traditional mathematics classroom. In this multi-site, multi-case qualitative study, I explored teacher perceptions of the use of vertical non-permanent surfaces on the impact of engagement, including the use of formative assessment and feedback with mathematics students, and the lesson structure of *360 Degree Math*. The study took place in a school district in the State of Georgia with 48 teachers teaching 2nd-12th grades mathematics. One major finding was the increase in the frequency and the manner of formative assessment of students and feedback to students with the implementation of VNPS based on teacher perception. The implementation of VNPS used during instruction in mathematics classrooms increased the opportunity for multiple student interactions and greater mathematics understanding.

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Chapter I: Introduction

Students in the United States have shown lower academic achievement on standardized mathematics assessments in the 21st century in comparison to the academic achievement of international students on the Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Studies (TIMSS) (McFarland et al., 2019; Provasnik et al., 2016; Sen et al., 2019; The Nation's Report Card, 2019). These assessments, which were intended to serve as a common measure of student achievement internationally, displayed widespread deficits for U.S. students regarding mathematical knowledge in comparison to students from other countries (McFarland et al., 2019). In accordance, the 2017 scores from the National Assessment of Educational Progress (NAEP) were less than satisfactory with an increase of students in the below basic level for 4th, 8th, and 12th grades (McFarland et. al., 2019). The United States scores on the national and international mathematics assessments indicated a need for instructional changes in mathematics classrooms for increased student engagement and comprehension of mathematics concepts to increase academic achievement (Erdogdu, 2019; Hattie, 2012).

The NAEP mathematics assessment is given every two years in the United States during the 4th, 8th, and 12th grade years to measure students' mathematical knowledge and skills, as well as their ability to solve mathematics problems with a relationship to real-world contexts (The Nation's Report Card, 2019). In 2019, 59% of 4th graders in the United States scored below proficient on the NAEP mathematics assessment, with 29% earning a score of below basic (The Nation's Report Card, 2019). The basic level for 4th grade students included the ability to complete simple computation with whole numbers with a very basic understanding of rational numbers and geometry (Provasnik et al., 2016). In 2019, 66% of 8th graders in the United States scored below proficient on the NAEP mathematics assessment, with 31% who scored below basic (The Nation's Report Card, 2019). The basic level of skills comprehension for 8th grade included the simple understanding of procedures with whole numbers, fractions, decimals, and percent (Provasnik et al., 2016). Achievement scores on the NAEP assessment at the basic level indicated students have skill deficiencies in the areas of problem solving, application, and the ability to justify mathematical understanding (Provasnik et al., 2016). The NAEP mathematics scores of 4th and 8th grade students in the United States during 2019 indicated a need for instructional change in mathematics classrooms to improve student achievement.

The PISA mathematics assessment was another international assessment that measured students' ability to use, interpret, and replicate mathematics concepts and procedures including the students' ability to take what they know and apply it to routine and non-routine situations (Provasnik et al., 2016). The PISA was administered every three years to 15-year-old students with a focus on students' functional mathematics knowledge near the end of their compulsory schooling (Sen et al., 2019). In 2018, 27% of 15-year-old U.S. students scored below level two on the PISA mathematics assessment and the U.S. mathematics average was below half of the other 72 education systems that tested and included China, Japan, United Kingdom, Canada, and Australia (Sen et al., 2019). The U.S. average score in 2018 was 478 and corresponded to a level two score, which indicated a student was able to use basic algorithms and procedures to solve simple mathematics problems with whole numbers (Sen et al., 2019). In 2018, only 8% of U.S. students scored advanced on the mathematics section of the PISA assessment, which indicated students were able to solve complex problems with rational numbers and model, analyze, and communicate their findings (Provasnik et al., 2016). Students in the United States earned an average score that was below half of the mathematics scores for advanced students in other education systems internationally (Provasnik et al., 2016). Based upon PISA assessment scores, math students at the secondary level in the United States were achieving at lower levels in comparison to students in other developed nations in the fundamental use of mathematics.

The TIMSS assessment was administered every four years to 4th and 8th grade students in over 60 countries. The TIMSS compared the knowledge and skills achievement of 4th and 8th graders on knowing, applying, and reasoning in mathematics internationally (Provasnik et al., 2016). In 2015, the 4th grade and 8th grade average mathematic scores dropped and the number of students who achieved in the advanced level, like the NAEP and PISA, had declined (McFarland et al., 2019; Provasnik et al., 2016). The NAEP, PISA, and TIMSS mathematics assessment results indicated alarming deficits in mathematical skills and problem solving with less than half of students proficient in skills necessary for U.S. students to be competitive internationally (The Nation's Report Card, 2019).

Based upon the dismal achievement results on international testing in mathematics there was a need to address the mathematical preparedness and academic success of U.S. students. The Common Core State Standards (CCSS) for mathematics were implemented in 45 states between 2010-2015 to promote the critical thinking, problem solving, and analytical skills assessed on the TIMSS, NAEP, and PISA (Chief Council of State Schools and National Governors Association Center, 2010). The standards were designed from research of the curricular standards of international education systems that out-performed the United States on international mathematics testing (Chief Council of State Schools and National Governors Association Center, 2010). The CCSS for mathematics were developed as a minimum set of standards per grade level for states to adopt. While the CCSS for mathematics established what standards students were expected to learn at each grade level, the standards did not dictate the instructional methods used to teach the standards or provide guidance on how to promote the critical thinking and problem solving skills that had been identified as areas of concern on the standardized assessments taken by U.S. students (McFarland et al., 2019). School district instructional leaders and classroom teachers were responsible for not only determining how to teach the standards but also what resources and materials were necessary to support instruction of the standards. Teachers were also responsible for differentiating instructional strategies for students' needs while simultaneously providing the academic rigor required for developing students' critical thinking and problem-solving skills embedded in the CCSS for mathematics (Chief Council of State Schools and National Governors Association Center, 2010).

Kearney et al. (2013) concluded, from over 10,000 classroom walk throughs, higher levels of student engagement were necessary to increase critical thinking and problem-solving skills in students and to increase rates of learner achievement. Skilling et al. (2016) determined, from a study of 30 teachers at 10 different high schools, secondary mathematics teachers do not necessarily know how to engage students using effective teaching practices that incorporate critical thinking. Skilling et al. (2016) found teachers who engaged their students implemented tasks for cognitive engagement, encouraged critical thinking, developed a safe environment through rapport with their students in recognizing effort, and centered on students' interests. Similarly, Liljedahl's (2016) study of a *thinking classroom* for secondary mathematics students resulted in engaged students in the understanding of mathematics with a higher cognitive demand. These studies highlighted the need for secondary teachers' knowledge of how to engage mathematics students, especially with tasks that require critical thinking and problem solving.

Liljedahl (2016) recognized traditional secondary mathematics classroom norms in North America hindered students from experiencing effective problem-solving practices that enhanced engagement and learning of mathematics. These classroom norms included the type of tasks that teachers chose to implement, the grouping of students, room organization, student workspace, assessment, and discourse with students. Traditional mathematics classrooms consisted of students sitting in rows, listening to the teacher relay mathematics knowledge, with students taking notes, working individually, while listing examples of problems provided by the instructor (Berg, 2011; S. Kavanaugh, personal communication, January 3, 2020; Yackel & Rasmussen, 2002). Liljedahl (2016) determined his model of *thinking classrooms* counteracted the traditional classroom norms by contributing to learning engagement. The model of *thinking classrooms* included methods of working collaboratively on problem solving tasks, visibly random grouping of students, the use of vertical non-permanent surfaces (VNPS) for student work, teacher questioning as discourse with students, and immediate assessment of students (Liljedahl, 2016). Liljedahl (2016) found the use of VNPS provided an avenue for a high level of engagement, including perseverance of exploring and completing problems, as well as discussion and participation among classmates (S. Kavanaugh, personal communication, January 3, 2020). The visibility of the student work on the vertical boards raised student accountability versus a student remaining anonymous or unengaged by sitting at a desk in the traditional setting (Liljedahl, 2016; S. Kavanaugh, personal communication, January 3, 2020). Di Muro (2006) supported the student need for active engagement in the learning process for understanding of mathematics content that *thinking classrooms* provided based upon the review of research. Kavanaugh (personal communication, January 3, 2020) found VNPS, along with the structure of *360 Degree Math*, allowed students to be actively engaged in the learning of mathematics and provided opportunities for real-time individual feedback. *360 Degree Math* was a structure for lesson implementation with the use of VNPS that supported learner engagement and emphasized immediate student formative assessment and feedback (Kavanaugh, 2013).

Kearney et al. (2013) stated learner engagement has a direct link to critical learner feedback. Constant formative assessment of student work was a weakness of teachers, that resulted in limited feedback to students (Klute et al., 2017). Van Petegem et al. (2008) found, from a study with 1,140 students, individual student feedback was not a strength of mathematics teachers, and the improvement of teacher feedback resulted in an improvement of student academic achievement. Teachers who identified and corrected student misconceptions and understanding overgeneralizations that students make based on continuous formative assessment and feedback increased students' learning of mathematics concepts (Di Muro, 2006). Students who received one-on-one feedback from their teacher had higher achievement results and exhibited higher levels of engagement than students who did not receive individual feedback (Kearney et al., 2013). Students' engagement increased with continuous activity-centered learning with immediate feedback on weekly assessments, but daily mathematics quizzes were more effective on student achievement as students were better able to monitor their learning (Sancho-Vinuesa et al., 2013; Shirvani, 2009). The use of VNPS and implementation of the lesson structure of *360 Degree Math* allowed for teachers to provide real-time, immediate daily feedback that resulted in student engagement, a common finding in the previous studies (S. Kavanaugh, personal communication, January 3, 2020).

Statement of the Problem

Science, technology, engineering, and mathematics (STEM) content are needed skills for our students to be competitive in the 21st century global economy. STEM jobs are outpacing all jobs with a demand for qualified employees to think creatively, critically, and logically (Lefkowitz, 2018). "Science, technology and engineering, so essential to the future success of our country, cannot thrive without practitioners having a solid mathematics foundation" (Lefkowitz, 2018, para 2). The problem with students learning mathematics within a traditional mathematics classroom was the lack of engagement, daily real-time feedback, and the lack of opportunity to display their understanding of the math concepts presented during their daily class time (Liljedahl, 2016; S. Kavanaugh, personal communication, January 3, 2020; Shirvani, 2009). The unengaged and passive nature of students as they received mathematics information during a traditional mathematics class ran counter to research findings that show increased student engagement when teachers implemented activity-centered learning and provided immediate feedback, which promoted positive student progress (Sancho-Vinuesa et al., 2013). The traditional mathematics classroom environment allowed for a handful of students to receive assistance, ask questions, and answer questions, which resulted in most students acting as observers while teacher feedback was limited to the few students who participated (Phelan et al., 2011; S. Kavanaugh, personal communication, January 3, 2020). Due to the lack of time and structure in a traditional mathematics classroom, teachers were not able to address every student's progress by checking in with each student by observing work or through discourse, to determine next steps in instruction (Phelan et al., 2011).

Students were able to avoid a teacher's attention in traditional mathematics classrooms by the act of *studenting* (Liljedahl & Allan, 2013). *Studenting* was originally described as the things that students do to learn new concepts, but the concept was later expanded to include things students do that do not help them to learn new concepts (Fenstermacher, 1986; Liljedahl & Allan, 2013). Liljedahl and Allan (2013) established five main *studenting* behaviors observed in classrooms from a study with 32 students in the 11th grade: amotivation, stalling, faking, mimicking, and reasoning. The study by Liljedahl and Allan (2013) found 79% of students subverted the intentions of the teacher by gaming behaviors of *studenting* that were not conducive to learning. All too often the behaviors of stalling, faking, and mimicking were observed in the mathematics classrooms to avoid the teacher's attention of being called upon or questioned on student understanding (Liljedahl & Allan, 2013).

Traditional mathematics classrooms do not allow for teachers to view all student work or mathematical thinking in real-time, resulting in the teacher not being aware of *studenting* behaviors that do not promote learning. Teachers have difficulty accurately assessing the level of their students' current understanding of the math concepts being taught when students exhibit *studenting* behaviors that do not promote learning (Liljedahl & Allan, 2013). The lack of constant formative assessment of students by teachers resulted in minimal revisions to teacher instructional plans to meet the needs of the students, thereby missing opportunities to advise or praise students' thinking (Klute et al., 2017). When teachers rely on summative assessments to determine the level of learning of students, teachers missed out on immediately acting on the information provided by frequent formative assessment to increase student understanding or to extend it by adjusting instruction (Chappuis, 2009). When teachers did not know in real-time where student misconceptions were occurring, it was difficult for teachers to act immediately to correct the misunderstanding of students, resulting in an academic gap for new concepts that built upon the previously taught concepts in mathematics (Chappuis, 2009; Klute et al., 2017).

Beyond mathematics teachers' class-level assessments, national and state assessments have been administered for comparison of progress to determine academic achievement and student mastery of grade level standards. In 2019, 64% of 4th graders and 69% of 8th graders assessed in mathematics on the NAEP in the State of Georgia scored below proficient and below the national average (The Nation's Report Card, 2019). The report on the State of Georgia Milestone End of Year Assessment for spring of 2019 indicated 51% of 4th grade mathematics students were below proficient and 65% of 8th grade mathematics students were below proficient on mastery of grade level standards (Georgia Department of Education, 2019). Given these large percentages of students identified as below proficient, the purpose of this qualitative multi-site, multi-case study was to examine teacher perceptions of the use of VNPS for student engagement and mathematics learning from daily formative assessment and student feedback, and the use of the lesson structure *360 Degree Math* in 2nd-12th grade classrooms in one school district in the State of Georgia.

Research Questions

The purpose of the following research questions was to determine teacher perceptions of the use of VNPS for student engagement and mathematics learning from daily formative assessment and student feedback in mathematics classrooms in a district located in the State of Georgia. The use of the lesson structure of *360 Degree Math* was also addressed with participants who had implemented the strategy in their classrooms. These research questions guided this qualitative study in determining the literature to review and the research methodology implemented. The focus of this study included the following research questions:

Research Question 1

What are teacher perceptions of student engagement using vertical non-permanent surfaces in 2nd-12th mathematics classrooms in a school district in the State of Georgia?

Research Question 2

What are teacher perceptions of daily formative assessment and feedback for individual students using vertical non-permanent surfaces in 2nd-12th mathematics classrooms in a school district in the State of Georgia?

Research Question 3

What are teacher perceptions of the lesson structure of *360 Degree Math* when implementing vertical non-permanent surfaces in 2nd-12th mathematics classrooms in a school district in the State of Georgia?

Conceptual Framework

Yackel and Rasmussen's (2002) study found students' perception of traditional teaching in the mathematics classroom was the instructor's role was characterized by the explanation and demonstration of procedures for solving problems, while the students' role was limited to receiving the information and following the procedures verbatim. Berg (2011) and Kavanaugh (personal communication, January 3, 2020) described the traditional classroom where passivity was the norm with a low level of engagement of students. In a traditional classroom, the feedback for students, or from students, followed teacher-centered instruction in the form of quizzes or tests after the instruction (Berg, 2011). When students were engaged, an increase of responses from students provided the feedback needed in real-time for the teacher to modify the lesson immediately (Berg, 2011; S. Kavanaugh, personal communication, January 3, 2020). The structure of a traditional mathematics classroom, however, obstructed teachers' insight of student learning when they relied on physical gestures, such as nods or thumbs up as feedback of understanding (Ball, 2011). Teachers needed to address student understanding by giving specific feedback that linked understanding to the details of the problem (Jacobs et al., 2010). Additionally, teachers needed to understand a student's question may not be representative of the whole group but rather the individual himself (Jacobs et al., 2010).

The conceptual framework of relevance to this qualitative study was teacher *noticing*. Teacher *noticing*, also referred to as professional *noticing*, was described by Jacobs et al. (2010) as *in the moment decision making* by a teacher. Jacobs et al. (2010) studied 131 teachers and found there were important shifts to teacher *noticing* teachers needed to build into their instruction to be effective. When a student provided a verbal or written explanation to a problem or question, the teacher's response goes through a series of conditions of interpreting, understanding, decision-making, and strategy recognition of the student's understanding of the task at hand (Jacobs et al., 2010). Criswel and Krall (2017) described teacher *noticing* as the recognition of, and response to, teaching events in real-time. Similarly, Leatham et al. (2015) included the time during instruction where a teacher responded to and built upon students' thinking. Teacher *noticing* practices were difficult and complex in nature as teachers needed to understand content practices and knowledge of content to be effective (Melhuish et al., 2015). In mathematics classrooms where students share their ideas regularly, the skill of *noticing* was an important element of effective teaching (LaRochelle et al., 2019). Ball (2011) recognized teachers needed specialization in the content, not just general content knowledge, which included the pedagogical practices for effective noticing to occur.

A supporting conceptual framework to this study was Math Knowledge for Teaching (MKT), otherwise known as specialized content knowledge (Ball & Bass, 2003; Ball et al., 2005). MKT was the mathematical knowledge used when teaching mathematics. Knowledge beyond the content, including pedagogy was essential to teach effectively, so teachers were able to analyze and correct student understanding as needed to relate content in practice (Ball et al., 2005). A theoretical framework that supported the conceptual frameworks highlighted in this qualitative study was Bandura's (1977) social learning theory due to its emphasis upon recognized and identified behavior learned through observation and imitating others. The social element of the act of watching or hearing other people perform a behavior encouraged action in one's own change in behavior (Bandura, 1977). Bandura's (1977) social learning theory corresponds with the social element of VNPS in *thinking classrooms*. The combination of the conceptual frameworks of teacher *noticing*, MKT, and the theoretical framework of social learning theory were relevant to the implementation of VNPS and the lesson structure of *360 Degree Math* as important concepts and theory that provided a foundation for this qualitative study on teacher perceptions of the impact of VNPS on student engagement and student learning through formative assessment and feedback in the mathematics classroom.

Significance of the Study

The significance of this qualitative research was to further the field of education by adding to the existing research-based best practices for students in the learning of mathematics concepts. The research findings will enhance the research on VNPS, best practices for engagement in the mathematics classroom, and teacher perceptions of student learning based on immediate formative assessment and feedback in the field of mathematics. New information and new literature on teacher perceptions of *360 Degree Math* will result from this study. School administration, mathematics teachers, and mathematics school support staff will benefit from this study as findings will share teacher perceptions on the impact of VNPS and *360 Degree Math* and the effects on student engagement and mathematics learning, including the daily act of formative assessment and feedback and the effects for classroom instruction. Additionally, the results of this study may benefit the planning of school buildings as a possible alternative construction of mathematics classrooms that may improve instruction that result in improved standardized assessment results. Another significance would be the planning for teacher preparation in the use of VNPS and *360 Degree Math* through local professional learning as a general expectation for instruction in the mathematics classroom.

It was necessary to gather data on teacher perceptions of the use of VNPS and *360 Degree Math* to determine the effectiveness of the strategies for engagement, formative assessment, and feedback for students in learning mathematics concepts in elementary and secondary classrooms to increase student achievement. Kindergarten-12th grade mathematics standards provide the foundation of math understanding and skills needed for the 21st century learner to support their future careers. There was a large amount of general research on formative assessment, feedback, and engagement, but there was very little research on the use of VNPS and no research available on *360 Degree Math*.

Descriptions of the Terms

I defined the following terms for the purpose of this study.

Engagement

Schlecty (1994) described engagement of students as students who are engaged with the work, want to learn about the work, persevere with the work, and find enjoyment when the work is accomplished. Engagement includes affective (emotional), cognitive (mental effort), and behavioral (observable behavior) actions by a student (Fredricks et al., 2004). For the purpose of this study, engagement will include the description above including time on task with the use of VNPS.

Feedback

Shute (2008) described feedback as information that is communicated to the student with intent to change thinking or behavior to improve learning processes and outcomes. Feedback provides students with information they need to understand where they are in their learning and what the next steps are (Brookhart, 2008). For the purpose of this study, verbal and written feedback will include the description above with feedback occurring between teacher and student, and student to student with the use of VNPS.

Formative Assessment

Brookhart (2008) described formative assessment as the act of collecting information from the student before or during instruction for use in improving student performance on the learning goals (the knowledge and skills of the standards). Formative assessment provides information for the teacher on their planning and delivery of clear lessons and assignments. For the purpose of this study, formative assessment will include the description above with informal formative assessment of observation and assessing student work with the use of VNPS.

360 Degree Math

Kavanaugh (personal communication, January 3, 2020) described the *360 Degree Math* as a structured lesson approach of teaching where students stand at dry-erase boards around a classroom forming social networks, while the teacher facilitates from the center of the classroom observing possible misconceptions and providing feedback in real-time. The classroom represents a social network of a learning community. For the purpose of this study, *360 Degree Math* will include the description above and the five steps of the lesson structure of *The Exchange*, *The Rewind*, *The Micro-lecture*, *The Practice*, and *The Proof* as referenced in Chapter II.

Vertical Non-Permanent Surfaces (VNPS)

Liljedahl (2016) described VNPS as vertical dry-erase boards installed on the walls of a classroom that allow students the opportunity to actively engage in displaying their work in mathematics class. For the purpose of this study, VNPS will include a vertical, dry-erase magnetic surface and space for each student to work math problems.

Organization of the Study

This study focused on teacher perceptions of the impact of VNPS and teacher views of student engagement, formative assessment and feedback, and student learning of mathematics concepts in 2nd-12th grade mathematics classrooms. The research consisted of five chapters. Chapter I included the introduction to the study, statement of the problem, the research questions, the conceptual framework, the significance of the study, and the description of terms for the study for the importance of mathematics learning. Chapter II entailed the review of the literature that supported the themes related to the use of VNPS in mathematics classrooms. Chapter III was composed of the methodology of the study including the population, data collection, analytical methods, research design, trustworthiness, limitations and delimitations, assumptions and biases around this multi-site, multi-case, qualitative study. In Chapter IV, I presented the analysis and results of the data collected, the answers to the research questions, and the summary of the findings from transcribed interviews and coding of the questionnaire. Chapter V identified the conclusions and recommendations of the study, which included the implications for practice and recommendations for future research to fill gaps in literature for VNPS and *360 Degree Math*.

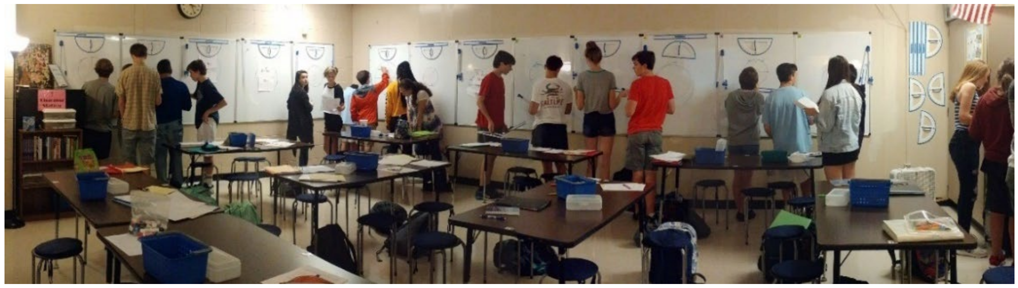
Chapter II: Review of the Literature

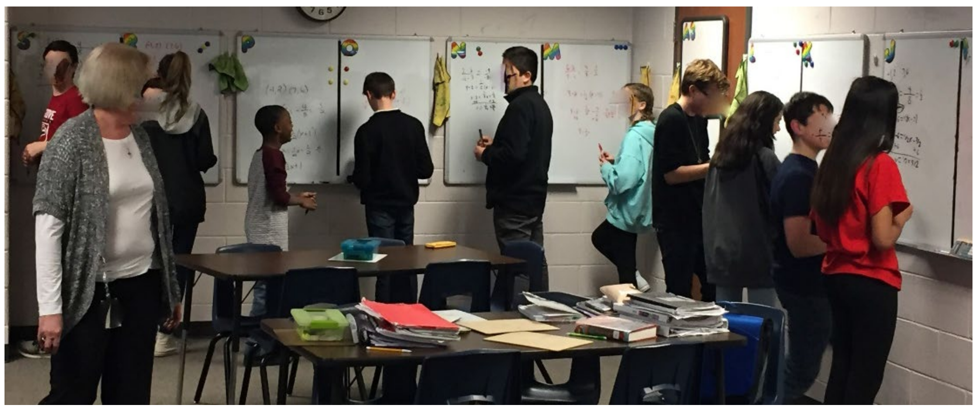
All too often when teachers deliver a lesson to students, student understanding is acknowledged by asking simple yes/no questions resulting in the lack of intentional individual student feedback and engagement of students (Ball, 2011; Brookhart, 2008; Fisher & Frey, 2014). Not all students have the discipline to self-regulate their learning by acting and controlling their learning environment to improve their understanding of material being delivered by the teacher (Fisher & Frey, 2014). Hattie et al. (2017) has reported from the analysis of thousands of studies that formative assessment and student feedback was in the top 10 of effective best practices in raising student achievement (Fisher & Frey, 2014; Hanover Research, 2014; Hattie & Timperley, 2007). It is important teachers gave students good feedback based upon their formative assessment of student work to engage the students in their learning (Brookhart, 2008).

How teachers assessed their students and provided feedback determined the effectiveness of implementation of classroom lessons (Hattie & Timperley, 2007; Shute, 2008). Hattie (2012) stated learning needed to be visible for teachers and accomplished teachers were evaluators with a wide range of strategies to build deep knowledge and understanding of concepts for students. Though there were numerous research studies on formative assessment and feedback, there was not a clear understanding of the most effective approach for strategic implementation of student formative assessment and student feedback that improved student learning and teacher instruction, especially in the field of mathematics (Dunn & Mulvenon, 2009; Hanover Research, 2014; Shute, 2008). Chappuis (2009) identified effective feedback occurred during learning, while students still had time to act on it. In mathematics, teachers struggled with formative assessment and providing real-time feedback to students in traditional classroom settings due to large class size and difficulty viewing all students' work at the same time (S. Kavanaugh, personal communication, January 3, 2020). The use of VNPS was a strategy and classroom design that deserved further research to determine if it was effective in assisting teachers with engagement, formative assessment, and immediate feedback to students (Liljedahl, 2016). In conjunction with VNPS, the lesson structure of *360 Degree Math* was of interest as it complimented VNPS for mathematics instruction (see Figure 1).

Figure 1

Example of a Traditional Classroom and a Vertical Non-Permanent Surfaces Classroom





Note: Top picture is an example of a traditional mathematics classroom. The middle and bottom pictures are examples of a mathematics classroom with vertical non-permanent surfaces.

Increased student engagement resulted from immediate formative assessment and student feedback when teachers were observed using VNPS (Liljedahl, 2016) and the concept of the *360 Degree Math* strategy in mathematics classrooms (Kavanaugh, 2013). There is no known research of teacher perceptions of the impact of VNPS on engagement through formative assessment of students and feedback given to students, including the structure of *360 Degree Math* in mathematics classroom instruction and student academic understanding. The following literature review focused on research of instruction for student learning in classrooms through student engagement with formative assessment and feedback and the use of VNPS and *360 Degree Math*.

Teacher Noticing

Mathematics classrooms were complicated environments where teachers attempted to be aware of student learning taking place and to respond to the actions and discourse of students in real-time (Jacobs et al., 2010). This response of teachers was related to the conceptual framework of teacher *noticing*. Researchers have coined the observation and reaction of teachers during instruction as *noticing* (Jacobs et al., 2010; Mason, 2002; van Es & Sherin, 2006). Jacobs et al. (2010) defined *noticing* as in the moment decision making while instructing. Goodwin (1994) established the beginnings of *noticing* through a professional vision that entailed teachers to view complex situations in particular ways tailored to the art of teaching. *Noticing* involved the teacher analyzing student strategies, interpreting and evaluating student understanding, and deciding on how to respond when teachers interacted with students (Mason, 2002). *Noticing* has taken on different labels such as intentional *noticing* (Mason, 2002), professional *noticing* (Jacobs et al., 2010), and teacher *noticing* (Melhuish et al., 2015). Each of these labels for *noticing* focus on expertise in the profession and making sense of what teachers attend to in their classroom instruction to effectively instruct (Jacobs et al., 2010; Mason, 2002; Melhuish et al., 2015). Mason (2002) determined probing student thinking was difficult, and teachers had to use their expertise in their profession to be able to switch instruction methods to adapt to students' reactions and interactions with the instruction. Teachers determined when a change to an alternative instruction technique was needed to reach the learner in the moment (Jacobs et al., 2010; Mason, 2002).

Stockero and Stenzelbarton (2017) suggested minimal support of professional learning for teachers did not assist teachers in being fully developed with the practice of *noticing* based upon their in-depth study of three teachers. Teachers needed on-going professional learning to fully develop the practice. Professional *noticing* was a challenge as many teachers are not well versed on how to attend to the details in the classroom and respond to individual students, but focused professional development and experience in *noticing* improved this weakness for teachers (Jacobs et al., 2010). Jacobs et al. (2010) recommended for teachers to be effective in *noticing*, they need to specifically address students' understanding, make connections to learning, and interpret individual responses over interpretation as group responses. Kilic and Masal (2019) stated, from their in-depth study of eight teachers, teachers do not always notice students' strategies and misconceptions. This lack of notice affects the feedback teachers give, as professional *noticing* on practices and content was an important part of effective teaching in classrooms where there was a large amount of discourse with students (LaRochelle et al., 2019; Melhuish et al., 2015).

Sherin et al. (2008) studied one teacher in-depth for mathematics teacher *noticing* through videos of instruction. The researchers found an effective three-part learning to notice framework for teachers. The first part was to identify important details of classroom situations. The second part was to use content and pedagogical knowledge to reason about classroom discourse. The third part consisted of the connection of classroom events to broader principles of teaching and learning. Sherin et al. (2008) stated teachers can improve their *noticing* techniques by changing what they notice and how they analyze and interpret the interactions in the classroom. Focused professional development on *noticing* helped teachers to consider individual students' thinking and make connections for students among different concepts.

Mathematics Knowledge for Teaching

A supporting conceptual framework to teacher *noticing* was MKT, otherwise known as specialized content knowledge (Ball & Bass, 2003). Mathematic teachers used their mathematical knowledge for effectively teaching mathematics content and pedagogy. Shulman's (1986) theory of content knowledge in teaching supported the relationship between the knowledge of content and the knowledge of the relating pedagogy. Shulman (1986) reviewed research and determined an effective teacher needed to know the how and why behind the content, the strategies for understanding and identifying misconceptions, and the vertical articulation of standards, including materials that support the teaching of standards. Similarly, Ball et al. (2005) stated teachers needed to have knowledge of teaching beyond the content knowledge to be able to analyze and correct students' understanding. When teachers were reviewing new material to teach students, the learner's perspective was a key component for teachers' planning for student understanding, which included judgements on the response and action with students when teaching was to occur. Teachers should have the background of four knowledge domains consisting of common content knowledge, specialized content knowledge, knowledge of students with the content, and knowledge of teaching with the content to teach effectively (Ball et al., 2005; Ball et al., 2008). Ball et al. (2008) recognized the four domains consisted of teachers knowing the cognitive difficulty of content, pure mathematical content knowledge for teaching the curriculum, student understanding and misconceptions, and the effective strategies or methods used to teach the content.

For teachers to learn MKT, they needed to be provided with opportunities to learn math concepts in conjunction with the pedagogy of teaching the math to students (Ball, 1988; Hoover et al., 2016). Hoover et al. (2016) recommended methods courses are more effective than content courses for the teaching of mathematics as the content should be embedded in the pedagogy. Mathematics content knowledge of a teacher did not always relate to the knowledge needed for effective instruction (Ball, 1988). Explicit understanding of the mathematics content was needed for teaching, as what a mathematics student learned during their school years did not provide the appropriate knowledge of mathematics to teach it (Ball, 1988). MKT generally impacts the teaching and learning of students including an increase in student achievement (Hill et al., 2005; Hoover et al., 2016). The amount of time set aside to teach mathematics, class preparation for the lessons, and MKT significantly related to student achievement gains (Jacob et al., 2017). MKT improved the analyzation of student work and, in turn, improved the explanations from teachers regarding common math rules and procedures that included the modeling of mathematics (Jacob et al., 2017). Shulman (1986, p. 14) simply stated, “Those who can, do. Those who understand, teach.”

Teacher Noticing, Mathematics Knowledge for Teaching, and Social Learning Theory

Noticing was commonly studied through pre-service teachers. Thomas et al. (2017) stated *noticing* was applicable to all teachers and it converged well with MKT. Daily, teachers needed fluid mathematical discourse with their students to provide effective instructional strategies for student understanding and provide highly individualized responses to students (Thomas et al., 2017). Thomas et al. stated " . . . professional *noticing* is the relationship between knowledge and practice" (p. 9). For teachers to be able to provide appropriate responses to students' thinking, teachers needed specialized mathematics knowledge to make instructional decisions to appropriately respond to students (Thomas et al., 2017). Though Thomas et al. (2017) was unable to conclude an empirical connection of MKT and *noticing*, the researchers believed a strong theoretical connection existed between the two theories.

Noticing and MKT are important components for teachers to relay content knowledge, analyze student responses, and determine strategies that best support students' understanding. Bandura's (1977) social learning theory supported the students' learning and understanding through the acts of attention, memory, and motivation. During the time of learning, students observed the consequences of their peers' actions without having to learn through trial and error (Bandura, 1977). Students learned by observation and direct experience of the interaction between cognitive, behavioral, and environmental influences (Bandura, 1977). Through observation and interaction, students' behavior may be influenced by someone modeling the desired behavior resulting in imitative learning through social learning (Bandura, 1977). The social interaction resulted in the cognitive development of individuals where they learn in a social setting then apply the learning individually (Vygotsky, 1980). Vygotsky's (1980) social development theory supported Bandura's (1977) social learning theory in that the observation of others in a social environment resulted in an individual working independently from the learning that occurred.

The conceptual frameworks of teacher *noticing* and MKT, in combination with social learning theory were important for this research on engagement, formative assessment and feedback in a mathematics classroom that implemented VNPS and for classrooms that implemented the lesson structure of *360 Degree Math*. VNPS are integral to the design of the mathematics classroom to visually see all students thinking and mathematics work at the same time, which may affect the *noticing* of teachers (Liljedahl, 2016; S. Kavanaugh, personal communication, January 2020). Jacobs et al.'s (2010) description of teachers' expertise as the skills of looking in detail at students' strategies, interpreting the students' understanding, and then responding to students' work was a focus of the teacher *noticing* framework that applied to instruction with VNPS. The use of VNPS required teachers to notice students' relational thinking, strategies, and misconceptions to respond appropriately and timely (Kilic & Masal, 2019).

Student Engagement

Teachers who implemented formative assessment and provided feedback to students encouraged engagement of the students through discourse between teacher and students or between student and student (Fisher & Frey, 2014). Fisher and Frey (2014) recommended four phases of instruction to check for understanding, to promote student engagement, and to encourage discourse in the classroom. The first phase called focused instruction provided a purpose for students with modeling by the teacher. The second phase consisted of students working collaboratively to learn more and retain information longer, if there was accountability for each individual student (Fisher & Frey, 2014). The third phase was guided instruction that supported students' learning through questions or prompts for feedback that promoted student thinking. The final phase was independent learning with the goal of students' application of information to a new situation.

Hattie (2012) completed over 1,000 meta-analyses of over 150 procedures and recognized six beliefs contributed to excellence in education in engaging students in their learning. Teachers needed to possess characteristics of being directive, caring, and powerful influencers of learning. Teachers needed to be actively engaged in teaching and passionate about student learning. Teachers needed to formatively assess all students and provide meaningful and appropriate experiences and feedback for students to move forward in their learning. It must be made clear to students of what they were to learn and the success criteria for learning. Teachers needed to make connections of ideas to build student knowledge. Schools needed to create environments where mistakes were learning opportunities and the culture reflected learning and re-learning as natural progressions of student progress (Hattie, 2012). Expert teachers created an engaged environment when they monitored student learning and engaged students with appropriate feedback of current understanding toward student success (Hattie, 2012).

Dotterer and Lowe (2011) stated classroom context (i.e., instructional quality, social/emotional climate, and student-teacher relationship) supported school psychological and behavioral engagement that attributed to academic achievement based upon their study of 1,364 students in 10 different schools across the United States. Behavioral engagement represented class participation and psychological engagement represented the affective and cognitive engagement of students feeling connected and competent in the work that resulted in motivation of the students (Dotterer & Lowe). Data were accessed from 10 locations in the United States consisted of 1,014 students in the 5th grade for a mixed methods study, where Dotterer and Lowe (2011) used standardized assessment data, observations, and self-report data for the study. The researchers determined on level or above level students who had positive classroom context demonstrated greater behavioral and psychological engagement than below level students. Psychological engagement corresponded to positive academic achievement with the students who did not have previous difficulty in academics (Dotterer & Lowe). A new finding in the study was students who had previous difficulty academically and had positive classroom context were behaviorally engaged in learning, but not necessarily psychologically engaged. The students who had previous difficulty academically did not display a positive relationship between behavioral engagement and academic achievement. The researchers found positive classroom context did not result in psychological engagement with students who had prior difficulty academically. Dotterer and Lowe concluded student engagement was a predictor of academic achievement while psychological engagement had a significant impact on academic achievement. For all students, instructional conversations and evaluative feedback contributed to instructional quality and the positivity of students in the classroom (Dotterer & Lowe, 2011). For students who have exhibited previous achievement difficulties, teachers needed to foster a sense of belonging and growth mindset that increased psychological engagement. Growth mindset, a phrase coined by Carol Dweck, implied the belief that students' recognition of their own effort increased academic growth and achievement, which was also supported by teachers' feedback focused on effort.

Collective Argumentation

Student psychological engagement was important in the mathematics classroom that promoted a growth mindset. Marshman and Brown (2014) investigated the use of collective argumentation for engagement of middle school students in mathematics with 27 students for a year-long study. Collective argumentation entailed a five-step process including a strategy sequence of representing individually, comparing co-operatively, explaining, justifying, and agreeing collaboratively, and validation communally (Marshman & Brown, 2014). The first step was for students to determine a solution path to a mathematic problem individually. The second step was for the students to compare their solution path in small groups of two-five students. The third step consisted of students comparing, explaining and justifying their solution path to come up with a consensus of one agreed upon pathway all the students understand. In the last step, the groups of students presented their pathway to the entire class (Marshman & Brown, 2014).

Throughout the collective argumentation process, the students provided each other feedback for the understanding of the other's pathways of learning. The teacher provided feedback during the small group time through discourse with the students to assist with understanding of the mathematics. The teacher role was that of facilitator of learning by engaging students in their understanding of the mathematics through questioning and feedback (Marshman & Brown, 2014). The researchers chose to study how collective argumentation promoted student academic engagement through a case study of one middle school mathematics classroom in Australia. Teacher and student journals were the primary sources of data collected for interpretative analysis (Marshman & Brown). Analyzation of the student journals by the researchers concluded the students' written comments positively influenced collaboration with other students and presentations to the class. The implementation of collective argumentation emphasized students' need for reflection and self-regulation through mathematical inquiry (Marshman & Brown, 2014). The communal validation was supported by Applebee et al.'s (2003) study of 64 classrooms of high- and low-achieving students who participated in classroom interactions with a discussion approach of an assessment conversation that was linked to higher student performance.

The use of collective argumentation promoted the sharing of mathematics solutions by students and collaboration by the students to reach a consensus on an agreed solution. Students and the teacher promoted understanding of the mathematics by utilizing questioning and feedback. Marshman and Brown (2014) determined the use of collective argumentation attributed to student engagement supported by the student journal entries consisting of 81% positive answers provided by the students. In the collective argumentation process, students shared their process in solving problems and received feedback through collaboration with other students. There were different modes in sharing student work where visual representations strongly supported mathematics reasoning (Marshman & Brown, 2014).

Reinholz (2018) made use of individual, hand-held, dry erase boards for active engagement of 129 calculus students in a large lecture hall loosely related to the collective argumentation strategy. Students were exposed to four active learning techniques of warmups, student presentations, think-pair-share, and group work. The techniques promoted student-to-student talk leading to class discussions. Based on the students' experience with the dry erase boards, Reinholz (2018) stated students regarded the dry erase boards as a positive teaching method for engagement. The use of the dry erase boards assisted in the acceptance of errors in practicing mathematics and promoted the interest of the instructor with student learning (Reinholz, 2018).

Berg (2011) found student engagement resulted in increased responses of students who provided teachers with the feedback needed to revise lessons in the moment of instruction. Traditionally, student passivity was the norm in classrooms and feedback to students typically came after instruction in the form of quizzes or assessments. This process of feedback resulted in low engagement of students, as only about 10-15% of students engaged with the teacher during instruction, which left the teacher not knowing what the understanding was of many students (Berg, 2011). Like Reinholz, Berg found dry erase boards used during instruction promoted engagement, leveraged immediate feedback to students, encouraged discourse among students, and promoted higher levels of thinking during instruction. Similarly, Zimmerman et al. (2018) found the use of dry erase boards and moveable desks allowed for students and instructors to move freely around the classroom and collaborate based upon four teachers' classrooms with 37 students. This interactive learning space promoted student engagement and positively affected student learning.

Studenting

When teachers were not able to visually see what students were thinking or grappling with in understanding math concepts, students may have exhibited *studenting* behaviors. *Studenting* was described as the things students do to increase their learning such as homework, studying, taking notes, and going to tutorials (Fenstermacher, 1986; Liljedahl & Allan, 2013). *Studenting* was also described as those things students do to avoid the intention of a teacher's lesson (Fenstermacher, 1986; Liljedahl & Allan, 2013). Liljedahl and Allan (2013) studied student behavior in a secondary mathematics classroom and found 79% of the students exhibited destructive *studenting* behavior that did not increase their learning. Examples of such behavior was amotivation, stalling, faking, mimicking, and reasoning (Liljedahl & Allan, 2013). Students who were not engaged found alternative actions to take during the time of practice (e.g., going to the bathroom, sharpening their pencil), and displayed behavior of looking like they were working or the act of using the procedure in their notes to answer a question. The students had learned to *game the system* and avoid accountability in completing the task that was administered (Liljedahl & Allan, 2013). Many times, teachers were not aware of *studenting* or gaming behaviors and assumed students were engaged with their learning. Formative assessment during instruction could have assisted teachers in knowing whether students were engaged with their learning or not.

Formative Assessment in the Classroom

Black and Wiliam (1998) reported from over 250 formative assessment intervention studies effect sizes ranging from 0.40 to 0.70, supporting the notion that formative assessment was one of the most effective practices in education in improving academic achievement (Hattie, 2012). Similarly, Hanover Research's (2014) review of research indicated the practice of formative assessment improved student academic performance. Formative assessment of students provided timely data of student understanding (Fisher & Frey, 2014). Leahy and Wiliam (2009) found rapid formative assessment (i.e., assessing two to five times per week) for learning in real-time of a lesson resulted in increased student achievement of 70-80% increase in the speed of learning. Five factors influenced assessment for learning: students' active involvement, effective feedback, adaptive teaching activities, students' self-assessment, and assessments affecting students' motivation and self-esteem (Hattie, 2012). Teachers checked for understanding through simple yes/no questions where most learners would sit quietly embarrassed to answer, as they were confused or not understanding the content (Fisher & Frey, 2014). The use of formative assessment had been identified as vital to supporting teachers in reflectively critiquing their instructional practice with the aim of improving classroom teaching (Shepard, 2008).

A formative assessment system of learning goals, student feedback, and adjustment of instruction performed by teachers assisted teachers in improved student achievement (Fisher & Frey, 2014). Learning outcomes of students improved with assessment criteria and objectives clearly stated to students for improving student's self-assessment ability (Hanover Research, 2014). Students needed to know where they were trying to go, where they were at that moment, and how they went about closing their learning gap (Chappuis & Stiggins, 2002; Hanover Research, 2014; Hattie, 2012; Hattie & Timperley, 2007).

Black and Wiliam (1998) identified five main strategies for the role of teacher, peer, and learner in engaging with formative assessment. The first strategy focused on clarification and understanding of learning objectives and success criteria. The second and third strategy stated the teacher's role in implementing tasks and student discussions showed evidence of student learning. The fourth and fifth strategy focused on student peer collaboration and student ownership of learning. Black and Wiliam (1998) found frequent formative assessment had a stronger impact on low-performing students over higher-performing students when the feedback concentrated on improvements to their work. Higher-performing students were impacted by feedback, just not as profoundly as low-performing students. Although there were critics to Black and Wiliam's (1998) study based on methodology flaws, limitations, and lack of empirical evidence, there was a body of literature that supported the notion that formative assessment under certain conditions can improve student learning (Dunn & Mulvenon, 2009; Hanover Research, 2014; Stiggins, 2005).

Hattie and Timperley (2007) characterized formative assessment into three phases: feed-up, feedback, and feed-forward. Feed-up was the act of clarifying the purpose of instruction with an objective or learning target for a focus of learning like Black and Wiliam's (1998) first strategy, which consisted of clarifying standards to students (Fisher & Frey, 2014; Hattie & Timperley, 2007). Feedback was the act of responding to student work about their progress and the course of action for students to take to improve their performance. Feed-forward was the act of modifying instruction based on formative data of any errors or misconceptions students may have based on the formative assessment data (Fisher & Frey, 2014; Hattie & Timperley, 2007). Hattie and Timperley (2007) recognized three phases that supported formative assessment, consisting of personalized learning and feedback for students, including teacher reflection on instruction that contributed to student understanding of concepts to master.

A review of 23 studies on formative assessment conducted by Klute et al. (2017) found formative assessment resulted in gains in academic achievement of elementary students with greater results in mathematics over reading and writing instruction. Klute et al. (2017) discovered student-directed formative assessment (i.e., self-assessment, self-regulation, or peer assessment) was effective for math and other-directed formative assessment (e.g., educator or computer program) was effective for both math and reading. Klute et al. (2017) reviewed the studies and determined formative assessment varied by subject area with larger effect size during mathematics instruction rather than in reading or writing instruction.

Formative assessment supported teachers' need to know students' understanding of content taught daily to determine what support was needed to move students forward in their learning (Fisher & Frey, 2014; Ruiz-Primo, 2011). To do this, one strategy of formative assessment was the use of informal instructional dialogues used with everyday activities. This informal formative assessment referred to as assessment conversations were student to teacher or student to student interactions (Ruiz-Primo, 2011; Ruiz-Primo & Furtak, 2006). The goal was to make students' thinking and understanding evident to teachers so they could adjust instruction as needed in real-time (Fisher & Frey, 2014; Ruiz-Primo, 2011; Ruiz-Primo & Furtak, 2006, 2007).

In a mixed-methods study of four middle school science teachers implementing assessment conversations, Ruiz-Primo and Furtak (2006) found the teachers who implemented assessment conversations with the elements of elicited student thinking, student response, teacher recognition of student response, and teacher use of information to support student learning resulted in higher performance of students. Ruiz-Primo (2011) reviewed research studies and determined a set of conditions needed for assessment conversations to be effective were comprised of a guided learning goal, a dialogic and interactive conversation, use of instructional scaffolding tools, supportive tools of social participation/cognition, and enculturation tools (Ruiz-Primo, 2011). Ruiz-Primo (2011) stated teachers need deep content and pedagogical knowledge to leverage assessment conversations to increase student learning. When teachers provided feedback to students through a discussion approach after formatively assessing them, other students benefited from the feedback as well (Ruiz-Primo, 2011). Frequent formative assessment of student performance was an effective practice that increased academic achievement and students' speed of learning. Teachers who repeatedly made use of formative assessments that allowed for students to understand learning goals, participated with their peers with continuous discourse, and received feedback to self-assess and self-regulate their own learning, resulted in teachers continuously modifying their instruction to meet the student needs to improve performance.

Feedback for Students

Feedback was an imperative factor of the formative assessment process where teachers provided direction and then redirection (Brookhart, 2008; Hattie, 2012). Shute (2008) defined formative feedback as ". . . information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning" (p. 154). Student formative feedback was intended to help students set new learning goals and develop a plan on how to achieve those goals (Brookhart, 2008). Formative feedback supported student learning when the teacher shared the goal for learning success, developed the opportunity for students to show their understanding, provided students with next steps, allowed for peer interaction, and promoted student ownership of learning (Black & Wiliam, 2009). Feedback was one of the most powerful moderators of learning for students, but Hattie (2012) found feedback had the most variable in effects of learning.

Kearney et al. (2013) indicated teachers who provided critical feedback to students promoted higher levels of learner engagement that led to positive academic achievement. Principals in nine public schools that consisted of six middle schools and three high schools completed 459 walkthroughs in 87 classrooms of secondary mathematics for the Kearney et al. (2013) study. The schools' student enrollments were 92 to 777 with 46.4%-95.1% of students who qualified for free or reduced-price lunch. The principals used the *360 Degree Walkthrough* collection instrument that assessed learner engagement and critical feedback from teachers (Kearney et al., 2013). The definition of critical feedback was stated in Texas' Professional Development Appraisal System Scoring Criteria Guide as "[t]eacher gives specific and immediate feedback, when appropriate; feedback pinpoints needed corrections; feedback provides clarification of the content; and feedback moves the student toward success with the learning objective" (Texas Education Agency, 2004, p. 22).

The multi-level analysis quantitative study involved the use of hierarchical linear modeling to determine a relationship between critical feedback and learner engagement from the *360 Database* of the recorded walkthroughs (Kearney et al., 2013). The researchers determined a positive statistical significance in the level of engagement of students who received higher levels of feedback from their mathematics teacher than those students who received lower levels of feedback or no feedback. Neither the school size nor the socioeconomic status affected the results of the research. Kearney et al. (2013) attributed the higher level of engagement in mathematics classrooms to teachers who provided specific individual feedback to students regardless of students' socioeconomic status or school size.

Timing of Feedback

Brookhart (2008) stated an important component of effective teaching was when teachers provided students with feedback on a regular basis, which resulted in increased student learning. Black and Wiliam (2009) stressed the instance of communication of feedback and the timing of feedback were essential principles of effective feedback. Wiliam (2011) added timing of feedback was crucial for students to have the time to act on the information and student preparation in receiving the feedback was needed to be effective. Teachers needed to provide feedback at a time that was beneficial for students, including time for students to think cognitively about how to approach revisions of their work (Wiliam, 2011).

Brookhart (2008) summarized feedback strategies from three major reviews into four categories: timing, amount, mode, and audience. The timing of feedback was when and how often feedback was given. Black and Wiliam (2009) emphasized feedback coupled with the possibility of implementation by the student when it was timely and specific. Feedback may be immediate, delayed, and as often as needed to direct students in their learning. Similarly, Hattie (2012) stressed the power of feedback was when the teacher knew when to provide it and when to step back and let the student persevere on his own. Timing of the delivery of feedback may be immediate or delayed and research was mixed on the effectiveness of each (Brookhart, 2008; Shute, 2008). Feedback needed to occur when students were still mindful of the current task and have a reason to continue to work on the task for it to be effective (Brookhart, 2008; Hattie, 2012). Immediate feedback resulted in positive effects of motivation to practice or negative effects of reliance on information that promoted less thinking on the learning of students (Shute, 2008). Hattie (2012) stated immediate feedback may reduce the learning of wrong information. Delayed feedback encouraged engagement in processing for higher level learners or it caused struggling learners to become frustrated (Shute, 2008). A study of 391 secondary students and 192 teachers indicated students do not find feedback useful unless it was timely for application, not just a correction of mistakes or a grade that followed an assessment (Brookhart, 2008; Havnes et al., 2012).

Delivery of Feedback

Direct feedback facilitated by teachers for error analysis and feedback that provided comments and suggestions to students was an effective instructional strategy (Black & Wiliam, 1998; Shute, 2008). Formative feedback may be delivered to students as verification of answers being correct or incorrect or elaborative feedback where responses may be specific or general (Shute, 2008). Effective feedback included both verification of the accuracy and elaboration of details (Mason & Bruning, 2001; Shute, 2008). Students were motivated to learn when the learning entailed two key components: a challenge for students to undertake and feedback received directly from the teacher to the student (Hattie, 2012).

Black and Wiliam (2009) argued the most effective feedback teachers provided to their students was when students were motivated to act upon the feedback provided. As such, Black and Wiliam (2009) stressed an essential principle of effective feedback was the delivery of the feedback to the students. Shute (2008) suggested emotions can interfere with learning and there may be a relationship between affective factors in feedback and student outcome performance based upon the review of close to 200 research documents. Black and Wiliam (2009) supported Shute's suggestion that emotions are involved with feedback, and it was crucial there was positive interaction with students to help them progress. Students' positive responses to feedback for success were imperative for student engagement and increased student performance (Black & Wiliam, 2009). Thus, the teachers' feedback was effective for students when they had the ability to influence students' affective domain by building their confidence in the learning intentions (Black & Wiliam, 2009).

Shute (2008) indicated feedback delivery in one-third of the formative feedback studies reviewed recognized negative effects of feedback on learning. The feedback characteristics of these negative effects were critical comments, use of grades comparing work to peers, vagueness, or interruption of active student thinking (Shute, 2008). Feedback was ineffective when it was vague, as its purpose was to guide students with a direction and a course of action for improvement of learning (Brookhart, 2008; Wiliam, 2011). Teachers needed to be wary of poor formative feedback for students that consisted of giving students a grade for an assignment meant for practice, telling students their work was good or bad, giving a reward or applying a punishment, and giving general praise or criticism (Brookhart, 2008; Hattie, 2012). It was important for students to receive feedback that was *forward-looking* and individualized about their progress on the work for it to be effective (Hattie, 2012).

To fill the gap of the learner, Hattie (2012) identified three modes of feedback: affective, procedural, and cognitive. Students may be addressed by the three modes separately or integrated with increased learning with words of encouragement, guidance in processing skills, and knowledge and understanding in acquiring the content presented. Brookhart (2008) stated feedback can be powerful when students cognitively understood where they were in their learning that resulted in motivation of students to use the feedback for control over their learning. It was important for students to realize constructive criticism was fundamental for learning to occur provided teachers gave students a chance to use it for improvement (Brookhart, 2008). Hattie (2012) pointed out, while integrating feedback into instruction was useful for students, the way it was given was similarly important. Thus, the relationship between the teacher and students and how the feedback was delivered determined its instructional effectiveness. Students' relationships with their teachers was important for feedback to impact students' understanding of next steps in their learning and teachers who gave students opportunities to improve their work were found to be more effective (Hattie, 2012).

Hattie and Timperley (2007) proposed four levels of feedback. The levels were feedback about a task on whether the results were correct or not, feedback about the process taken to complete the task, feedback about self-regulation of student abilities, and feedback about the student as a person (Brookhart, 2008; Hattie & Timperley 2007). The first two levels were more effective for students to understand for learning, but the latter two encouraged students to put forth more effort toward the task. Hattie (2012) recommended teachers should leave praise out of feedback (i.e., feedback about the student as a person) intended for learning as it had been found to have a low effect size compared to no praise that had a greater effect. Teachers often use praise to comfort and support students, but it does not provide the attention needed for learning to occur. If praise was used for feedback, it needed to be separated from the feedback on the accuracy of their performance or the procedure that was used to complete the task at hand. Hattie

(2012) stated for feedback to be useful in learning, praise should not be included, as it reduces the students' attention to feedback of learning outcomes.

The inconsistencies in research may be explained by the individual differences of motivational prerequisites for feedback, which Shute (2008) refers to as intrinsic motivation, personal beliefs, academic achievement goals, academic self-efficacy, and metacognitive skills. One motivation for students to act on feedback was through the process of written feedback on student work in lieu of feedback with grades, as students would typically ignore the feedback and focus on the grade (Black & Wiliam, 2009; Shute, 2008; Wiliam, 2011). The amount of feedback was the determination of how many points would be used to redirect students that was appropriate for their developmental level and addressed the major learning goals (Brookhart, 2008). The mode of feedback was either oral, written, or visual, and possibly through a demonstration. Brookhart (2008) recommended interactive feedback with students as often as possible. Feedback given to individual students or to the class depended upon whether a few students needed to be redirected or the lesson needed to be retaught in its entirety to students (Brookhart, 2008).

Content of Feedback

In addition to the feedback strategies Brookhart (2008) summarized from a review of research, the content of the feedback was equally important. Feedback content was given to focus students on one of the four levels of feedback by Hattie and Timperley (2007) that consisted of the work, the process, student self-regulation, or the student personally (Brookhart, 2008). The feedback content was a comparison to exemplary work or a function of evaluation of student work.

Feedback content could be positive or negative for students, but the negative feedback needed positive suggestions for improvement to occur. The feedback content needed to provide clarity for the student with specificity that assisted the student to know what their next steps were (Brookhart, 2008). Students' response to feedback started at the task level that determined what was accurate, where the process level included detail of where a student erred (Black & Wiliam, 2009). Good feedback with respect for the student, worded so the student takes ownership for their work, was effective when it caused students to think about the action to take to improve their performance (Brookhart, 2008). The final level was self-regulation, where students recognized an awareness of self-monitoring in how they looked at their work in the future (Black & Wiliam, 2009; Brookhart, 2008). Feedback was crucial for students to understand their performance and the effectiveness of the method they chose to complete a task, and it positively contributed to student ownership of their work.

Researchers who explored the effects of feedback for students during instruction indicated students who received higher levels of feedback were more likely to be engaged, build upon prior knowledge, and produced higher levels of academic achievement (Fyfe & Rittle-Johnson; 2015; Kearney et al., 2013). Fyfe and Rittle-Johnson investigated the effects of students who received feedback versus students who did not receive feedback with instruction. The researchers studied 209 students in 2nd and 3rd grades from two public schools and one private school. The students who exhibited no prior knowledge of the mathematics content of equivalent problems participated in the study (Fyfe & Rittle-Johnson, 2015). Students received instruction regarding a correct strategy for solving the problems and classrooms were randomly assigned to one of three groups for experimental feedback. The three groups consisted of no feedback, immediate-feedback, and summative feedback.

Fyfe and Rittle-Johnson (2015) reported students with no knowledge of a correct strategy responded positively to right-wrong verification feedback by demonstrating higher procedural knowledge. Students with prior knowledge of a correct strategy demonstrated higher procedural knowledge and conceptual knowledge than if they did not receive feedback. When students received feedback immediately when they completed work or if they received feedback as a summative to wrap up multiple works, the effectiveness of the feedback was found to be the same (Fyfe & Rittle-Johnson, 2015). The researchers concluded low-knowledge learners benefit from formative feedback while higher-knowledge learners did not benefit from formative feedback in the same way. Hattie et al. (2017) stated feedback from teachers to students who have mastered material has little effect on understanding. Errors were the basis for feedback to improve understanding, and these are not reserved for lower-achieving students (Hattie, 2012). If feedback did not provide a challenge for students, then feedback was of little value. No matter the level of the student, feedback can be provided to suggest the next step in learning (Brookhart, 2008).

In contrast to Fyfe and Rittle-Johnson (2015), Baliram and Ellis (2019) determined content-specific feedback coupled with metacognitive strategies influenced student achievement in high school mathematics. The convenience sample for the study consisted of five Honors Geometry courses with 75 students at a private school. The students were in either an experimental group or a comparison group. The experimental group received content-specific feedback on their practice problems and metacognitive prompts written on notecards (Baliram & Ellis). The participating teacher received a summary of the students' misconceptions or areas of struggle after each of the 12 feedback interventions. Both groups completed an end-of-unit assessment that revealed the experimental group scored higher than the comparison group that did not receive reflection questions or practice problems with content-specific feedback. Baliram and Ellis (2019) proposed content-specific feedback coupled with formative assessments resulted in improved learning and higher academic achievement. Systematic use of formative feedback in supporting student learning was considered an area for growth for classroom teachers (Havnes et al., 2012). Thus, researchers suggested to provide quality feedback, teachers must appropriately determine when, how often, how much, and to whom the feedback is most beneficial to increase student understanding and learning (Brookhart, 2008).

Vertical Non-Permanent Surfaces

Many math classrooms resembled the traditional mathematics classrooms of the past where students sat in rows, received instruction from the teacher, then completed workbooks or worksheets with practice problems (Berg, 2011; S. Kavanaugh, personal communication, January 3, 2020). The physical setting of rows of desks was not conducive to collaboration, sharing of student work, or teachers being able to effectively formatively assess students due to the physical construct and time limitation of a teacher visiting every student desk (S. Kavanaugh, personal communication, January 3, 2020). Reinholz's (2018) use of individual dry erase boards with the design of students sitting in rows in classrooms supported Liljedahl's (2016) research on the effects of VNPS, otherwise referred to as vertical dry erase boards, for the development of thinking classrooms in mathematics that encouraged engagement and collaboration of students. Liljedahl observed the ineffective results of students sitting at desks in rows and focused on student workspace for a thinking classroom. The observation of students sitting at desks to standing and working on the mathematics led to an experiment of the effects of permanent and non-permanent horizontal surfaces and vertical surfaces used for student work. Liljedahl (2016) studied 155 students in five high school mathematics classrooms that implemented activities and teaching methods learned in teachers' professional learning team meetings. This was the first time teachers had used different surfaces for learning with all students rather than having one student demonstrate learning for all in the front of the room. Students were in groups of two to four, and each group was provided one of five surfaces to work math problems: VNPS, horizontal dry-erase whiteboard on desks or a table, flipchart paper on the wall, flipchart paper on desks or a table, and notebooks on desks or a table (Liljedahl, 2016).

Liljedahl (2016) measured the effectiveness of each of the surfaces based on rating the students with *proxies for engagement* (i.e., time on task, time to first mathematical notation, eagerness to start, discussion, participation, persistence, non-linearity of work, and knowledge mobility) (Liljedahl, 2016). Each group received a problem-solving activity to complete on the different surfaces. Observers collected the data to determine the average scores for each surface based on the eight measures. The VNPS beat out the other surfaces in *proxies of engagement* of eagerness, discussion, participation, and knowledge mobility. The

VNPS tied horizontal whiteboards for student persistence and came second to the vertical paper with time to task. The time to student notation was quicker in the notebooks versus the VNPS, but the notion of students writing their name or titling their paper may have led to this result. Liljedahl (2016) stated the use of VNPS produced more *thinking classroom* behavior and increased both whole-group collaboration and inter-group collaboration of students when they worked together on problem solving.

Liljedahl (2016) followed up the student study with a study that focused on the use of the VNPS with 300 teachers. Elementary, middle, and secondary teachers participated in the study over a four-year period after they attended a one-day or two-day workshop. Liljedahl interviewed the teachers and visited classrooms and determined once teachers used VNPS with their instruction, many of those teachers continued to use it past the initial implementation. Based on the interview data and the field notes from the observations, teachers reported the engagement of their students and the teacher's practices had evolved. Interview data and field notes included participants sharing how VNPS changed their teaching practice and increased the enthusiasm of students in all grade levels. Of the 300 teachers in the study, 96-100% intended to continue to use VNPS due to the immediate effectiveness of instruction (Liljedahl, 2016).

Berg (2011) found dry erase boards that were individually held or on a wall surface allowed for teachers to know more about the effectiveness of their lessons, including where to begin instruction and what interventions were needed for students on a regular basis. The dry erase boards provided a quick formative assessment to know what students were thinking immediately and a platform for easy corrections of mistakes. Berg (2011) concluded teachers needed effective strategies and good questioning techniques to use with the dry erase boards to be effective with instruction. Pruner's (2016) study of four high school classes on the use of VNPS in a mathematics thinking classroom aligned with Berg (2011) and Liljedahl (2016) in that VNPS intrinsically motivated students to learn mathematics. Similarly, Kavanaugh (personal communication, January 3, 2020) agreed with Pruner (2016) who found students were engaged and enjoyed learning mathematics with VNPS.

360 Degree Math

An effective use of VNPS was implemented by Kavanaugh (2013) along with an instructional lesson structure that incorporated engagement of students with instant formative assessment and feedback for the mathematics teacher called *360 Degree Math*. Social, neurological, and educational research laid the foundation for this approach to teaching math (Kavanaugh, 2013). Weller (2015) reported the neurological act of movement while working a math problem rather than sitting still at a desk helped an individual in reasoning with a math problem. Reynolds (2015) concluded students who sat still for long periods of time had a reduction in cardiovascular performance affecting their nervous system. Kavanaugh (2013) made use of dry-erase boards on the classroom walls for students to work, identical to VNPS, which replaced the traditional classroom design of desks in rows to combat the unhealthy habits of sitting still and promoted active learning in a social setting. The shift of students sitting passively at their desks to working math problems by standing at the boards allowed the teacher to become a facilitator of learning. The teacher as facilitator of learning promoted student-centered instruction. Cubukcu (2012) stated student-centered instruction put the responsibility of the learning on students by having them play an active role in the learning process. Students work together, which resulted in improving their critical thinking and problem-solving skills. Students who took part in discussion with their classmates helped them to better understand the content to be learned (Cubukcu, 2012). The active engagement of students positively impacted their learning and helped them to construct knowledge (Cubukcu, 2012). Kavanaugh (2013) stated the teacher was able to quickly observe students' work by standing in the center of the classroom and provided instant feedback to students including clarification of misconceptions individually and to the group. The speed the teacher was able to provide feedback to students increased since the teacher did not have to check student work by walking desk-to-desk, repeatedly explaining misunderstandings or directions (Kavanaugh, 2013).

Kavanaugh (2013) designed five steps to approach daily mathematics lessons with students using the vertical dry-erase boards:

- The first step was *The Exchange*, where the teacher positively greets each student at the door and provides him with a marker and eraser.
- The second step was *The Rewind*, where students work on the boards with three math problems that have a connection to prior learning and one challenge problem to build confidence.
- The third step was *The Micro-Lecture*, consisting of 10 minutes of direct instruction. During this time, students received information

regarding new vocabulary and/or math concepts with sample problems. The students took notes during the lecture step.

- The fourth step was *The Practice*, where students return to the boards to work independently on given problems with a chance for discussion and collaboration with their peers. During this time, the teacher guided students in their learning.
- The fifth step was *The Proof*, where students shared their understanding by completing a formative assessment. The teacher determined the next day's lesson based on the results of the assessment.

The structure of lessons was imperative for cadence and flow to visually see student work for effective instruction (S. Kavanaugh, personal communication, January 3, 2020). Each class period the student filled in *The Progress Bar* (as string of numbers representing problems located above their boards) to see their own progress on mastery of problems after receiving feedback from the teacher. The use of technology by the teacher assisted students in seeing the chart of progress filled in real-time (S. Kavanaugh, personal communication, January 3, 2020).

During the 2012 school year, Kavanaugh (2013) reported Martin Luther King Jr. Early College (MLK JR EC) 6th-9th grade students in Denver, Colorado, within the Denver Public School District performed 78% below proficient in mathematics on the Transitional Colorado Assessment Program (TCAP). The population of students was 68% Hispanic, 27% Black, and 5% White. The implementation of *360 Degree Math* in the 6th-9th grade mathematics classrooms occurred during the 2012-2013 school year. MLK JR EC 2013 mathematics TCAP had higher gains in median growth percentile with 6th-9th grade students than any other school in the district (Kavanaugh, 2013). The gains in median growth percentile were between 9-12% for each grade level. MLK JR EC out-performed all the schools in the district in Algebra I when comparing the median growth percentile. Kavanaugh (2013) attributed these gains to implementation of the lesson structure of *360 Degree Math* with one year of instruction and the use of VNPS. Teachers responded to Kavanaugh's (personal communication, January 3, 2020) push of implementation of VNPS and *360 Degree Math* positively by claiming they would never go back to teaching traditionally again. Teachers improved their implementation of the use of VNPS and *360 Degree Math* through professional development and observing students in action. It was recommended data were collected daily by teachers to differentiate through small group instruction and independent work. The differentiation was implemented during personalized learning time where guided discourse and/or modeling practices were used in the *360 Degree Math* structure in small group instruction (S. Kavanaugh, personal communication, January 3, 2020).

Summary of Review of Literature

A traditional classroom of students sitting in rows and passively receiving information from a teacher did not promote student engagement with learning. When students were actively engaged, retention and understanding of concepts increased, which resulted in increased academic achievement. To increase student engagement, researchers found students who experienced regular formative assessment and individual feedback from teacher *noticing* was most effective. The feedback from teachers experienced in a positive social and emotional climate promoted a growth mindset in students. The collaboration of students instilled through social learning experiences engaged students, which caused lessened negative *studenting* actions. The MKT increased personalized feedback for students and connections to other related concepts students were learning. The use of VNPS resulted in the observation of student engagement, immediate formative assessment and feedback, and peer observation for construct of knowledge.

In this literature review, I provided background for this qualitative multi-site, multi-case study on teachers' perceptions of the use of VNPS and the *360 Degree Math* structure for impact on student engagement, formative assessment of student understanding, and personalized feedback for students to promote academic achievement. In Chapter III, I outlined the methodology applied to answer the research questions. The research design, role of the researcher, sample of the study, data collection procedures, method of analysis, trustworthiness, limitations and delimitations, and assumptions were also addressed.

Chapter III: Methodology

It was important for mathematics teachers to assess daily their students' conceptual growth in mathematics and provide real-time feedback to students regarding their progress toward meeting standards (S. Kavanaugh, personal communication, January 3, 2020). Excellence in teaching, as summarized by Hattie (2012), required teachers to be aware of students' thinking and knowledge to provide meaningful and appropriate feedback. Teachers who formatively assess their students and provide immediate feedback encouraged higher levels of student engagement and ultimately contributed to higher levels of academic achievement (Kearney et al., 2013; Perry, 2008). The purpose of this qualitative multi-site, multi-case study was to examine teachers' perceptions of the use of VNPS for student engagement and mathematics learning from daily formative assessment and student feedback and the use of the lesson structure *360 Degree Math* in 2nd-12th grade classrooms in one school district in the State of Georgia. The focus of the collection of data was to answer the research questions of teachers' perceptions of students' engagement, the impact of formative assessment and feedback in mathematics classrooms who implemented VNPS. Additionally, the strategy of *360 Degree Math*, a lesson structure that complimented the use of VNPS, was implemented by a sub-group of participants, and teachers' perceptions of the impact of this strategy was included in the data collection. In this chapter, I detailed information on the research design, my role as the researcher, the sample of the study, and the data collection method of the perceptions of teachers regarding the impact of the use of VNPS in mathematics instruction and the implementation of the *360 Degree Math* lesson structure. This chapter concluded with a discussion of the trustworthiness of the data collection, the limitations and delimitations of the study, assumptions of the study, and a summary of the methodology of the study.

Research Design

The research design for this study was a qualitative multi-site, multi-case study of one school district in the state of Georgia. The difficulty of qualitative research was maintaining objectivity where quantitative research primarily focused on numerical data for more objectivity (Lichtman, 2013). This qualitative research relied on the researcher being the primary instrument for data collection of participants' perspectives to gain meaning in context of the implementation of VNPS (Bogdan & Biklen, 2007; Merriam & Tisdell, 2016). Merriam and Tisdell (2016) described qualitative research as focused on the insight and understanding of the perspectives of participants of the study for noteworthy contributions, especially to the field of education. A holistic description and explanation of the phenomenon was essential for insight, discovery, and interpretation of this qualitative research (Merriam & Tisdell, 2016). I was the captive audience responsible for the accuracy of rich and in-depth description of participants' views of their ideas and actions under study (Bogdan & Biklen, 2007).

Because the focus of this study was on capturing the perceptions of participant experience in the implementation of VNPS, the use of a non-probabilistic, purposeful sample was applicable to this descriptive, interpretive study. Creswell (2012) described a purposeful sample as one with intentional selection in understanding a phenomenon. To gain insight into teachers' perceptions of the impact of VNPS on their mathematics classrooms, I implemented selective processes for participant identification and data collection, which will be described in further detail in this chapter.

Yin (2014) stated multiple methods within a study may be used such as a questionnaire within a case study or a case study within a questionnaire. This study contained a questionnaire within a multi-case study. This qualitative study used data from virtual, semi-structured in-depth individual interviews and a virtual semi-structured focus group interview with select participants located in their classrooms and allowed for the study to be viewed holistically in their natural setting (Wiersma & Jurs, 2009). The semi-structured approach was supported with a developed protocol of preplanned questions, but it was important the group lead the discussion to gain valuable insight on their experience with VNPS (Lichtman, 2013). Data was used from responses of an electronic questionnaire (See Appendix A) typed into the website, SurveyMonkey, filled out by 46 participants in this study. Participants from multiple school sites and multiple grade levels had implemented VNPS in their classrooms within this one school district, that accounted for this multi-site study. Participants from different grade levels were interviewed and responded to the questionnaire to gather data on similarities and differences of their perceptions of the implementation of VNPS, that attributed to this multi-case study. The focus of this multi-site, multi-case study was on mathematics teachers' perceptions of student engagement, formative assessment and feedback for students following implementation of VNPS, including a sub-group who implemented the lesson structure of *360 Degree Math*. Teachers' perceptions were important for the practice of education as they were in the field instructing students daily and had a better understanding of their students' reactions to the implementation of an instructional strategy. The teachers' perceptions were useful to other educators as they provided insight concerning whether an instructional method was worthy of classroom implementation.

Role of the Researcher

My role as the researcher in this qualitative study was to serve as the primary instrument for data collection and analysis (Merriam & Tisdell, 2016). Qualitative research involved interviewing participants in their natural setting for better understanding of a phenomenon to gather, organize, and interpret information (Bodgan & Bilken, 2007; Lichtman, 2013). I interviewed participants virtually in their natural setting of their classroom that contained VNPS. Reality was constructed by me through interpretation and personal background as data were collected and analyzed (Lichtman, 2013).

Lichtman (2013) stated I should have experience and understanding of the topic being studied because I was responsible for gathering the data and filtering the data for analysis. I realized my own experience and knowledge of VNPS could effect the interpretation of data, as I did my best to be unbiased and objective. To reduce subjectivity, I exercised reflexivity by reflecting on my own values related to the research and instituted member checks of the transcribed interviews for accuracy of responses (Lichtman, 2013). I had no direct role in supervising the participants for evaluation of their performance in the classroom; instead, I assumed a neutral role. In this qualitative research, I viewed the study in totality and analyzed participant perspectives to construct understandings derived from the data collected (Merriam & Tisdell, 2016).

In this qualitative study, I determined what research questions to examine and what data to collect, implementing reflexivity throughout the entire process. The decisions were based upon my experience, knowledge, and skills, including background in relation to the topic. I served in the role of mathematics support for the district in the study but was not an evaluator of any of the study participants. Although I did not experience the use of VNPS by directly teaching a mathematics class with students, I provided the initial professional learning for some of the district participants who had implemented VNPS in their mathematics classrooms based upon the reading of research by Liljedahl (2016). I had the opportunity to experience VNPS with 12 math teachers working towards a certification. The professional rapport and collegiality I had previously constructed with the participants was advantageous and helped to create an environment of trust.

Participants of the Study

The purposeful sample of this study consisted of 48 mathematics teachers from 2nd-12th grades within a school district in the State of Georgia. A purposeful sample of participants was identified using the following criteria: participants taught math daily to students between 2nd-12th grades; VNPS was currently used in participants' classroom instruction; participants had received professional learning on VNPS implementation; and participants provided access to VNPS for all students. The qualification of 2nd-12th grades was based upon the school district's installation of VNPS in those the grade level classrooms. This purposeful sample met the requirements of the research and provided information for a rich description for this multi-site, multi-case study (Wiersma & Jurs, 2009). Of the prospective participants invited to take part in the study, a sub-group had attended professional learning on the strategy of *360 Degree Math* for the implementation of this lesson structure with VNPS.

I determined the participants for the study through school district records provided by the mathematics department in identifying the installation of VNPS in classrooms in each of the identified 20 elementary schools, 25 middle schools, and 17 high schools. and the attendance of participants in VNPS professional learning, including the sub-group of participants who attended the *360 Degree Math* professional learning. After receiving university and district approval for the research, principals of the schools with the prospective participants were contacted for approval of the participants to take part in the study. The district mathematics department provided the emails of prospective participants whose classrooms contained VNPS and who had attended professional learning. When the principals approved for their requested participant(s) to be contacted, I sent the approved prospective participants a voluntary electronic questionnaire by email that included a consent form (See Appendix C) during August 2020. Forty-six participants teaching 2nd-12th grades volunteered to fill out the questionnaire and included their name if they were interested in participating in the voluntary, virtual individual interview or the virtual focus group interview, that allowed for in-depth collection of additional data. The interviews were completed virtually due to the social distance restrictions instituted by the school district during the Covid-19 pandemic. Two participants emailed me to volunteer to be interviewed, but they did not fill out the questionnaire.

The participants to be individually interviewed were selected based upon their teaching of 4th, 8th, 9th, 10th, or 12th grades during VNPS implementation, which corresponded to the grade levels assessed by the NAEP, PISA, and TIMSS assessments. Sixteen participants teaching the previously listed grade levels who attended the VNPS or *360 Degree Math* professional learnings and implemented VNPS regularly were invited to the individual interviews. Of the 16 invited participants, 10 participants accepted the invite and set dates for August 2020 and September 2020 to be individually interviewed. The participants' classes included diverse student populations such as co-taught, on-level, and advanced mathematics courses, allowing for richer conversation that included the differentiation of scaffolded and enriched content. The in-depth individual interviews allowed for participants to share their own perceptions of the impact of VNPS that may not have been revealed with as much detail in the larger focus group interview or within the questionnaire. The 10 participants included three elementary school teachers, four middle school teachers, and three high school teachers.

The participants selected for the virtual focus group interview included those participants that attended the *360 Degree Math* lesson structure professional learning in January 2020 and July 2020. Fourteen participants who attended professional learning of the *360 Degree Math* lesson structure strategies and taught 4th, 8th, 9th, 10th, or 12th grades were invited to the semi-structured focus group interview for September 2, 2020. All 14 participants accepted the invite. Of the 14 focus group participants who accepted the virtual invite, six participants logged in to the interview, but two left the interview during the first question due to unexpected school commitments. The four interview participants who stayed the entire interview included one elementary school teacher, one middle school teacher, and two high school mathematics teachers.

All the participants in this study were employed as certified staff teaching mathematics during the implementation of VNPS in the school district between the fall of the 2017-2018 school year to the 2020-2021 school year. The academic degrees earned by the participants ranged from a bachelor's degree to a doctoral degree, with over 75% of participants having the equivalent of a master's degree or higher. At the time of the interviews and the circulation of the questionnaires, the participants' range of teaching experience varied from four to 27 years. For confidentiality purposes, each interview participant was assigned a pseudonym of *T* with a number.

T1 participated in an individual interview. T1 had a specialist degree in leadership and had taught eight years in elementary school. They began implementing VNPS in their 4th grade classroom during the 2019-2020 school year. Their school departmentalized for mathematics and they served as the mathematics teacher for 4th grade. T1 had attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T2 participated in an individual interview. T2 had a specialist degree and had been teaching 14 years in elementary school. They began implementing VNPS in their 4th grade classroom during the 2018-19 school year. T2 had attended professional learning for the implementation of VNPS.

T3 participated in an individual interview. T3 had a master's degree and had been teaching seven years in elementary school. They began implementing

VNPS in their 4th grade classroom during the 2019-20 school year. Their school departmentalized for mathematics and they served as the 4th grade mathematics teacher. T3 attended professional learning for implementing VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T4 participated in an individual interview. T4 had a master's degree and had been teaching for 12 years in middle school. They began the implementation of VNPS in their 8th grade mathematics classroom during the 2017-18 school year. T4 attended professional learning for implementing VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T5 participated in an individual interview. T5 had a master's degree and had been teaching for 25 years in middle school. They began the implementation of VNPS in their 8th grade mathematics classroom during the 2017-18 school year. T5 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to implement the strategies learned.

T6 participated in an individual interview. T6 had a bachelor's degree and had been teaching for 14 years in middle school. They began implementing VNPS during the 2018-19 school year in their 8th grade mathematics classroom. T6 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T7 participated in an individual interview. T7 had a master's degree and had been teaching for 17 years in middle school. They began implementing VNPS during the 2018-19 school year in their 8th grade mathematics classroom. T7 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T8 participated in an individual interview. T8 had a bachelor's degree and had been teaching for four years in high school. They began implementing VNPS during the 2018-19 school year with their 9th grade mathematics students in Algebra I. T8 attended professional learning for the implementation of VNPS but did not attend the *360 Degree Math* session. They have the hope of participating in future professional learning regarding *360 Degree Math*.

T9 participated in an individual interview. T9 had a doctoral degree and had been teaching for 18 years in high school. They began implementing VNPS during the 2018-19 school year with their high school mathematics students. T9 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T10 participated in an individual interview. T10 had a master's degree and had been teaching for eight years in high school. They began implementing VNPS during the 2018-19 school year with their high school mathematics students. T10 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T11 participated in the focus group interview. T11 had a master's degree and had been teaching for 20 years in elementary school as a 4th grade teacher and in the role of academic coach. They began implementing VNPS during the 2019-20 school year. T11 attended professional learning for the implementation of VNPS through the *360 Degree Math* session with the expectation to continue with the strategies learned.

T12 participated in the focus group interview. T12 had a master's degree and had been teaching for 16 years in middle school as an 8th grade mathematics teacher. They began implementing VNPS during the 2018-19 school year. T12 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session, with the expectation to continue with the strategies learned.

T13 participated in the focus group interview. T13 had a specialist's degree and had been teaching for 24 years in middle and high school as a mathematics teacher. They began implementing VNPS during the 2017-18 school year as a high school mathematics teacher. T13 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session, with the expectation to continue with the strategies learned.

T14 participated in the focus group interview. T14 had a master's degree and had been teaching for eight years as a high school mathematics teacher. They began implementing VNPS during the 2018-19 school year. T14 attended professional learning for the implementation of VNPS, including the *360 Degree Math* session with the expectation to continue with the strategies learned.

T15-T48 were the participants who responded to the questionnaire only. Participants were identified as elementary, middle, or high school level mathematics teachers.

Data Collection

Creswell (2012) identified five process steps in data collection: identification of the participants through purposeful sampling, permission for the research and more access to a site for interviews, determination of data resources such as observations and interviews with a researcher-developed instrument, recording of the information collected with researcher-designed protocols, and ethical considerations when gathering information in person. The website SurveyMonkey was used for the questionnaire I developed for participants to answer the research questions on the teachers' perceptions of the impact of VNPS in their mathematics classrooms. I developed an interview protocol (See Appendix B) for consistency among the individual interview participants and the focus group interview participants. The electronic questionnaire and the protocol for the individual interviews and the focus group interview (see Appendix B) were pilot tested by three academic coaches that represented elementary, middle, and high school levels at the district schools where VNPS was implemented, but the coaches did not participate in the study. The academic coaches tested the questionnaire virtually through SurveyMonkey and participated in a virtual mock interview to check for clarity that resulted in revisions and refinement before being sent to prospective participants.

After the university Institutional Review Board granted approval of the research in July 2020 and the local school district granted approval of the research in August 2020, the principals of the requested schools were contacted for consent of inviting their identified teachers who represented the purposeful sampling of implementing VNPS to participate in the study. Sixty-two principals were emailed, but 10 schools were removed from the list after I was informed of the schools having new teachers in the classrooms with VNPS who had no experience using the boards or from the lack of principal approval. After principal approval was received, the electronic questionnaire that contained demographic and open-ended questions to address the research questions were emailed to all

52 teachers identified as prospective participants teaching 2nd-12th grades during August of the 2020-2021 school year to gauge their perceptions of VNPS and *360 Degree Math* (if applicable) from multiple perspectives and multiple grade levels. An informed consent form was included in the email to the participants and included an option to withdraw from the study at any time. The questionnaire remained open for participant completion for four weeks. The participants' profile data were collected through the questionnaire to identify years of teaching experience, highest degree attained, time implementing VNPS, whether they attended professional learning from the school district on VNPS, and their experience with *360 Degree Math*. The participants that implemented VNPS for the 2019-2020 school year stopped using VNPS during the end of March 2020 when students were sent home for virtual instruction due to the Covid-19 pandemic. A total of 46 participants voluntarily completed the questionnaire by the middle of September of the 2020-2021 school year.

The participants that completed the questionnaire included their name if they were interested in participating in the virtual individual interview or the focus group interview. The interviews were conducted through the Microsoft Office platform using the Teams application. I conducted in-depth, virtual interviews with participants who provided more insight on the impact of VNPS and *360 Degree Math* that included multiple views from the different grade levels. The participants completed their interviews within their classrooms that contained VNPS during August 2020 and September 2020. The interviews were conducted virtually due to the school district's guidelines for the Covid-19 pandemic that limited in-person contact with participants.

From the names provided on the questionnaire, 16 participants that taught 4th, 8th, 9th, 10th, or 12th grades and met the criteria for the research of VNPS were contacted to participate in virtual individual interviews during August of the 2020-2021 school year. Ten participants responded to the request and the interviews were conducted during agreed dates and times convenient for the participants. The interviews took place in the participant's classrooms containing VNPS during August and September of the 2020-2021 school year. The 10 virtual individual interviews were video-recorded on Microsoft Teams and I recorded field notes that were saved to an external drive. The individual interviews lasted between 15 and 30 minutes each. The individual interviews captured the participants' perceptions of what they have experienced and learned regarding the impact of VNPS and *360 Degree Math* in their mathematics instruction. The individual interviews exposed the commonalities and differences at each site and grade level classroom.

A purposeful sample of 14 prospective participants who implemented VNPS and the *360 Degree Math* lesson structure and taught 4th, 8th, 9th, 10th, or 12th grades were invited to participate in a virtual focus group interview through the Microsoft Office Teams application during September of 2020. These participants attended professional learning on the implementation of *360 Degree Math* in January of 2020 and received a second professional learning on advanced *360 Degree Math* lesson structure strategies in July 2020. Six participants that implemented components of the *360 Degree Math* lesson structure attended the focus group interview, but two participants left the meeting at the start of the first question due to unexpected commitments within their schools. The focus group interview lasted 45 minutes and was video recorded with field notes taken by me. The focus group interview allowed for more participants to provide rich, contextual data of their perceptions of the impact of VNPS and *360 Degree Math* in their classrooms. This focus group interview allowed for multiple perspectives, with participants sharing a range of views, which promoted dialogue among the participants of their ideas and experiences with VNPS (Bogdan & Bilken, 2007). The combination of interviewing participants and collecting perceptions of participants through an electronic questionnaire provided a foundation for understanding the impact of VNPS in mathematics classrooms and the lesson structure of *360 Degree Math*.

Methods of Analysis

Data analysis in this multi-site, multi-case qualitative study began immediately after the first set of data were collected from the questionnaire (Wiersma & Jurs, 2009). This study required organization of the data with constant comparison by the researcher through an ongoing process throughout the study as more data was collected (Wiersma & Jurs, 2009). I downloaded the data from the questionnaire in SurveyMonkey to a Microsoft Excel document for weekly analysis during the four weeks that the questionnaire was active in August and September 2020. The Excel document was organized by question and participants' responses to the open-ended questions were separated by elementary, middle, and high school levels to investigate similarities and differences between the grade levels. Open-ended question responses were compared with like demographic responses to investigate any noteworthy trends. The responses of all participants were coded by question in a new tab in the Excel sheet to summarize ideas. Coding was the act of using symbols, words, numbers, and colors from text data and dividing the text into sections to view any overlap or redundancy in the data (Creswell, 2012; Merriam & Tisdell, 2016). At the end of the four weeks, the demographic question responses from the questionnaire were assigned percentages to each number scale for each question answered by the participants.

The individual interviews and the focus group interview video were transcribed verbatim and were downloaded from Microsoft Office Teams application and saved to an external hard drive. I formatted the interviews into a Microsoft word document and corrected any discrepancies in the wording based upon the recorded interview videos. The transcriptions were sent to the participants to check for corrections or revisions. Referred to as member checking (Creswell, 2012), participants reviewed the accuracy of their interview transcriptions and highlighted corrections. As the interview participants returned the corrected transcriptions, the data were coded by elementary, middle, and high school responses in a new tab in the Excel sheet for each of the questions asked from the interview protocol.

Triangulation of the data was performed to determine themes based on the perceptions of participants' impact of the implementation of VNPS and the implementation of the *360 Degree Math* lesson structure with the sub-group of participants. The triangulation of data consisted of two techniques for collecting data including the questionnaire and virtual interviews for cross-validation and corroboration for better understanding of the phenomenon (Bogdan & Bilken, 2007; Wiersma & Jurs, 2009). Simultaneous data collection and analysis occurred at the onset of the collection of the questionnaire, the individual interviews, and the focus group interview. This allowed for a constant comparison of data to occur during the coding process that assisted in developing categories and emergent themes that accurately represented the cross-checked data collected (Merriam & Tisdell, 2016). The questionnaire and interview questions were aligned to each research question. A new tab was created in the Excel sheet to record the combination of the codes from the questionnaire and the interviews questions that aligned to each research question separated by elementary, middle, and high school responses. The coding for elementary, middle, and high school grade levels were compared for similarities and differences. This resulted in a cross-case analysis of responses. The combination of the coding from the triangulation were analyzed for organized categories representing subtopics and themes of major topics (Creswell, 2012; Merriam & Tisdell, 2016). The themes were cross-checked with the research questions for the desired information (Merriam & Tisdell, 2016).

From the coding of the data, categories, then themes emerged with common threads of topics. The themes were detailed descriptions that developed from the commonalities of the coding (Creswell, 2012). I implemented reflexivity throughout the data analysis by reviewing field notes and interview videos with reflection upon body language and emotion during the interviews when the data were reviewed to reduce bias and assumptions (Merriam & Tisdell, 2016). Participant responses were reviewed and highlighted for ideas and quotes that answered the research questions. The investigation of this multi-site, multi-case study allowed me to gain a deeper understanding of teacher perceptions from various grade levels and population demographics about the impact of VNPS on student engagement, formative assessment, and feedback, and the implementation of *360 Degree Math*, which answered the research questions of the study.

Trustworthiness

To ensure credibility and dependability of the research, I applied strategies to verify trustworthiness, as was suggested for qualitative studies (Lichtman, 2013). The first was the use of pilot testing of the questionnaire and interview protocol with three academic coaches from the district schools who had a teacher using VNPS within their building. The pilot test of the questionnaire and interview protocol was to make certain the questionnaire and interview protocol were clear and concise for teacher input and that each data collection method addressed the research questions (Merriam & Tisdell, 2016). I made use of triangulation of multiple sources of data using the questionnaire and interviews to develop trustworthiness of the methods and instruments used to analyze the data. The triangulation contributed to a holistic understanding of the study (Merriam & Tisdell, 2016).

Participants were informed of the steps taken to ensure the protection of their privacy and the confidentiality of their responses. Lichtman (2013) highlighted ethical considerations of not intruding on participants' personal time, informed consent and a choice to participate, and the avoidance of misinterpretation, all of which were followed in this study. An informed consent form was provided to all participants, allowing for any participant to remove themselves from the study at any given time. Participants were treated as professionals in a polite and respectful manner with a focus of a safe environment.

Pseudonyms were used to maintain the confidentiality of participant responses and references to specific schools were not included in the data.

Member checks were performed for those who were interviewed to confirm the interpretative data were reasonable. Member checks involved the review of field notes and transcribed interviews of participants performed at regular intervals for feedback to me (Merriam & Tisdell, 2016). Member checks were performed continuously throughout the study to make sure the results were credible and my bias was mitigated (Lichtman, 2013; Merriam & Tisdell, 2016). I was cognizant in interpreting the data to report only on the participants' perceptions of the impact of VNPS and *360 Degree Math* and not perceptions of other stakeholders. A triangulation of the data was performed for final themes and answers to the research questions. Triangulation is the process of comparing multiple sources of data as a cross-validation for better understanding (Bogdan & Bilken, 2007; Merriam & Tisdell, 2016; Wiersma & Jurs, 2009).

My biases were addressed in the section on assumptions of the study. The use of a multi-site, multi-case, qualitative study enhanced the credibility of the data as meaning was constructed by me (Merriam & Tisdell, 2016). Though my role as researcher was in close proximity of the participants, my reflexivity assisted in reduced biases and personal influence on the study to stay focused on the perceptions of the participants by openly discussing my role in the study with the participants (Creswell, 2012; Lichtman, 2013). This qualitative research was focused on my interpretations of multiple perspectives within the study and allowed for a sense of subjectivity (Lichtman, 2013). The purpose of this qualitative multi-site, multi-case study was to examine teacher perceptions of the use of VNPS for student engagement and mathematics learning from daily formative assessment and student feedback, and the use of the lesson structure *360 Degree Math* in 2nd-12th grade classrooms in one school district in the State of Georgia

Limitations and Delimitations

As with all research studies, the design of this qualitative study was susceptible to limitations. Limitations were factors that may have caused problems with the study that are not within the control of the researcher (Creswell, 2012). Limitations of this study included unexpected interruptions and availability of participants for the interviews. The availability of the teachers selected was an issue in August of 2020. The unexpected closing of the school district in March of 2019 due to the COVID-19 pandemic left participants with the task of getting their classrooms in order and a new set of lessons plans to create in August that included preparation for future virtual learning. The school year was delayed for two weeks to prepare for virtual instruction. The lack of research regarding VNPS and no research on *360 Degree Math* was a second limitation of the study as research was the basis of the literature review. The literature review established the theoretical foundation of the study to assist in focusing the research. Though there were teachers across the United States and a few rural districts in Georgia that have been implementing VNPS, there was limited research on the impact of VNPS and no research on the lesson structure of *360 Degree Math* in mathematics classrooms. The identification of the gaps in the literature related to teacher perceptions provided evidence of a need for further research with VNPS and *360 Degree Math*. The time designated for the study was a third limitation. The limited time for interviewing the 14 participants provided a baseline of the implementation of VNPS, to be able to analyze the results for the transferability to other populations. Merriam (2016) stated qualitative research is not to try and generalize the research, but to understand the data in depth from the study through rich, thick description.

Delimitations in this study were the boundaries placed on the participant population by the researcher (Simon, 2011). The study was delimited to mathematics teachers in 2nd-12th grades within one public school district in the State of Georgia who had implemented VNPS and were continuing to implement VNPS. A second delimitation was prospective participants were only teachers who previously attended professional learning for VNPS, with some participants having also attended professional learning for *360 Degree Math*. I was a third delimitation due to previous experience with VNPS of assisting participants with installation in their classrooms, providing the initial training and arranging professional learning for *360 Degree Math*. It was expected that participants would have answered truthfully without any feeling of obligation to me. I reduced subjectivity by triangulating the data, incorporating member checks and collecting data to the point of saturation where themes emerged (Merriam & Tisdell, 2016).The study was still worthwhile as the perceptions of the participants of the effectiveness in using VNPS and *360 Degree Math* was relevant to other mathematics teachers and districts interested in implementing these strategies or who are currently implementing the strategies.

Assumptions of the Study

Assumptions were the factors of the study that were typically taken for granted, out of control of the researcher, but make the research relevant (Simon, 2011). An assumption of this study was the expectation that the participants would answer the questions on the questionnaire and during the interviews truthfully. The voluntary participants who answered the questionnaire retained confidentiality and their answers remained confidential to encourage honest answers. The voluntary participants who were interviewed were given pseudonyms to maintain their confidentiality. At any time, the participants were able to withdraw from the study with no ramifications. A second assumption was the questionnaire and interview questions were appropriate and succinct for answering the research questions. A pilot study of the questionnaire and interview protocol was performed for clarity for the participants and to assure they addressed the research questions. There was a third assumption that participants genuinely wanted to participate in this study without any motive in receiving special treatment of materials for their classrooms regarding VNPS. Included in this assumption was the notion that the participants received the same quality professional learning, they were provided the opportunity to use what they learned, and they implemented VNPS with their students on a regular basis. A fourth assumption was the qualitative multi-site, multi-case study methodology chosen by me was appropriate for the collection and analyzation of the data.

Summary of Methodology

This multi-site, multi-case qualitative research study focused on multiple data points. Data from an electronic questionnaire and virtual interviews were collected from 48 participants to glean a broader perspective of the impact of the implementation of VNPS's and *360 Degree Math*. A range of participants volunteered for a semi-structured focus group interview that encouraged further, more detailed discussion of the impact of the strategies. Voluntary participants were interviewed individually for a more in-depth perception of the impact of VNPS. The data collected from 48 participants throughout the study was constantly reviewed and cross-checked through coding, the development of categories, and the emergence of themes. I instituted reflexivity consistently throughout the data collection and analysis. The results answered the research questions focused upon teacher perceptions of the impact of VNPS and 360 Degree Math on student engagement, formative assessment, and feedback provided to students in mathematics instruction as outlined in Chapter IV.

Chapter IV: Analyses and Results

The purpose of this qualitative multi-site, multi-case study was to examine teacher perceptions of the use of VNPS for student engagement and mathematics learning from daily formative assessment and student feedback, and the use of the lesson structure *360 Degree Math.* The study centered on 48 participants in elementary, middle, and high schools teaching mathematics in 2nd-12th grades in one school district in the State of Georgia. Participants were contacted and I collected data using an electronic questionnaire, voluntary, virtual individual interviews, and a voluntary, virtual focus group interview. The intention of this chapter was to report the findings of the data as they related to the three research questions that were central to the purpose of this study. The data of the research findings in this chapter were collected and analyzed to provide answers to the research questions, with relation to the conceptual frameworks of teacher *noticing* and MKT, including Social Learning Theory.

Data Analysis

The findings of the participant response data in this multi-site, multi-case qualitative study were analyzed to answer the research questions. The participants invited to take part in this study included 16 high school teachers, 21 middle school teachers, and 15 elementary school teachers who had implemented VNPS within their instruction. The voluntary questionnaire was completed by 46 of the 52 participants invited, with a participation rate of 90%. In addition, data were collected from 10 voluntary individual virtual interviews with three elementary, four middle, and three high school teacher participants. Data collected from a voluntary focus-group virtual interview with one elementary, one middle, and two high school teacher participants were included. A total of 48 participants contributed to the study (two of the interview participants did not fill out the questionnaire).

Once I transcribed the interviews into a word document, the transcriptions were member-checked by the participants to ensure accuracy of the content (Creswell, 2012). I read through each of the interviews after the member checks were completed and made notes regarding the consistency of responses. I began the analysis process with a preliminary exploratory analysis of the questionnaire responses and interviews as they were received to get a general idea of the data collected (Creswell, 2012). After the preliminary review, I began highlighting the interview text and divided the text into segments identified by codes or descriptive words within the data (Creswell, 2012). The process was repeated with the responses to the questionnaire. The descriptive words from the interviews were gathered and typed into an Excel document for each question, separated by each participant. Each participant was assigned a pseudonym to ensure confidentiality. Each week, the responses from the electronic questionnaire on SurveyMonkey were exported by me. Through an iterative process, I added text and coding of the responses received and revised codes as needed.

The responses of participants who completed both the questionnaire and interview were combined for a holistic view. The remaining questionnaire respondents were assigned pseudonyms and their responses were highlighted with respect to the identified codes and were placed into a notebook for reference for support of emergent themes. The common codes from the questionnaire were added to the Excel file with the interview data within a separate tab. The common codes from the individual interviews and the focus group interview were combined and separated by elementary, middle, and high school levels within the Excel file. Through an iterative process, the interview data and the questionnaire data were combined as there were many common codes between the grade levels. The new codes were reviewed and reduced to represent categories, and the categories were reduced to major ideas or themes for the data (Creswell, 2012). The themes were narrowed to holistically represent all the participant responses from the study of teachers' perceptions of the impact of VNPS in mathematics classrooms. Lastly, the demographic questions were recorded, and percentages were assigned for each number of participants who answered the choices on each question.

Of the participants, 14 had implemented VNPS for 0-1 year representing 29% of the participants and 34 had implemented VNPS for over one year representing over 71% of the participants. All but two participants had attended the school district's professional learning for VNPS, but they had attended the *360 Degree Math* professional learning. Only one out of the 46 participants responded to the questionnaire that they were neither likely nor unlikely to continue using VNPS with his instruction, while the remaining 45 participants (98%) stated they would likely or very likely continue to use VNPS with their instruction. When participants were asked if they preferred a classroom with VNPS for mathematics instruction versus the traditional math classroom with desks, 40 out of 46 participants, equating to 87%, preferred VNPS, and six participants preferred a mixture of both VNPS and desk use in their rooms. The *360 Degree Math* lesson structure professional learning presented by Kavanaugh in January 2020 was attended by 36 of the participants, and 21 participants began implementing the strategies immediately. Of the 21 participants that implemented *360 Degree Math*, 19 participants stated they would continue using the strategies.

Research Questions

Research Question 1

What are teacher perceptions of student engagement using vertical non-permanent surfaces in 2nd-12th mathematics classrooms in a school district in the State of Georgia?

I reviewed the engagement responses from the questionnaire and the interviews. Descriptive responses from questions 11 and 15 from the questionnaire and responses from questions one and five from the interview protocol were recorded and separated by elementary, middle, and high school responses (see Table 1).

Table 1

Codes on Engagement with Vertical Non-Permanent Surfaces Developed into Themes

CODES		
Elementary	Middle	High

Accountable Behavior better Confidence increase Movement-standing On-task Collaboration increase Excitement Growth mindset Help each other Like using markers/boards Proud of work Quick to begin tasks	Accountable Behavior better Confidence increase Movement-standing No hiding Participation increase On-task Risk taking Understanding increase Collaboration-community Enjoy it Like using markers/boards More practice completion Quick to begin tasks Peer pressure View peer's work	Behavior better Collaboration increase Confidence increase More practice completion Movement-standing Accelerated classes like it Accountable Community Excitement Get help quicker Happier about math Like using markers/boards
COMBINED CATEGORIES		
Accountable Better behavior Collaboration increase Confidence increase Enjoy-excitement Like using markers/boards Movement-standing		
THEMES		
On-task Behavior Growth Mindset Community of Learners		

Note. The first row of the table represents codes from the three grade bands. The second row of the table represents developed categories from the combined codes. The third row represents the emergence of three general themes from the three grade bands.

The descriptive words identified as codes were listed for each of the three grade bands from the questionnaire and the interviews. Each column of codes were alphabetized. Commonalities were noted for elementary, middle, and high school responses and were recorded under categories. Three general themes emerged for teachers' perceptions of the impact of VNPS on engagement of students and consisted of improved *on-task behavior*, *growth mindset*, and the development of a *community of learners*. The three themes represented behavioral engagement (on-task behavior), affective engagement (growth mindset), and cognitive engagement (community of learners) of students.

On-task Behavior. A prevalent commonality across grade levels to describe the engagement of students with VNPS was the perception of on-task behavior described in a variety of ways. Participants consistently responded with students having better participation with class work. T19 stated, "I saw students who normally would not do their work sitting at their seat participate when they were able to write at their board." T4 shared, "VNPS greatly increases student engagement by enabling students to work together, allowing different students to become leaders in the classroom. The opportunity to not participate is not an option. All students participate equally." The term accountable was a common description for students being at the boards as they were not able to hide from working math problems or work on something other than the math. Only four participants out of the 48 shared examples of off-task behavior of students drawing on the boards or students not wanting to stand at the boards. Descriptive words and phrases, such as lazy, students didn't like being at the boards, fearful, and anxious students were shared as issues with implementation of VNPS by the four participants who taught middle or high school. T14 shared of behavioral engagement leading to a growth mindset:

> For me before the boards, it was a challenge to get that student who sat there and just kind of waited for you to do the problem . . . it felt like when they came into the room, I mean they immediately went to the boards and started working. Even if they weren't sure, they would try something.

Responses of behavioral engagement of all students standing up and moving was commonly noted and spoken about with positivity. T3 and T8 felt the students standing at the boards improved students' focus and attention, and T8 shared, "The students need the physical break of being able to stand after sitting for long periods during the day." Three interviewed participants shared their administration responded positively about seeing students standing at the boards collaboratively working math problems. T12 felt it was good for students to get up and move around as it was "effective and energizing for them." T4 shared an experience with a student that the movement at the boards made a difference for academic achievement:

> I had a student this last year who was in on-level [8th grade] math class and he was super quick to absorb things. He was [attention deficit-disorder] and he just wanted to be up and moving. So, I finally allowed him to have a seat near a board and he could go to his board and do what he needed to do. He was so quick that he could just do the work. He is now taking accelerated math in high school. His mom emailed me [and said] he just can't sit still because to concentrate, he needs to be standing and moving. You [the teacher] gave him a chance to do that. So, I feel like

that's an example of a student whose academic performance was able to rise to his potential. He had this potential that he hadn't been able to get to before [the use of the boards].

Participant responses described the absence of *studenting* behaviors with the use of VNPS. All the interviewed participants, and many responses from participants on the questionnaires, reported the observation of greater participation of students, better student behavior, and experienced less discipline problems with VNPS as it increased student engagement. T3 found the movement of students at the boards made a difference with boys' behavior by helping them to focus and stay on task. They elaborated on the improved discipline:

> Students have become much less defiant when beginning work time and exhibit less avoidance behaviors when they become stuck while solving [problems]. I can address undesired behaviors more quickly, which may have an impact on the decrease [undesired behaviors]. While these behaviors have certainly not disappeared from my classroom, they have become much less frequent.

Participants stated students were quick to begin their work at the boards, including completing more class work than in the traditional math classroom setting of sitting at the desks. T8 shared the increase in completion of mathematics problems kept the students engaged and helped the class time move quickly. T5 acknowledged a common perception of behavioral engagement from the participants' implementation of VNPS:

> I can say with all honesty that has been the biggest positive in my math class. I have the engagement, especially when they're at the boards. And

> the way I do it, they don't know when they're going back and forth to the boards. So, when I say they come in and they start the warm up on their boards, then we sit down for some instruction with me. Then, in the middle of instruction, I'll say to go to your boards and they actually get up without hesitation to go to the boards. To get them to start doing the math, it's probably maybe three seconds. Where if I have them sitting at the tables or at their desk, it was a struggle just to get them to do anything. Every year the students get more and more engaged with the math and I don't have classroom management problems because of it.

T12 believed, "There's definitely a level of excitement the kids have about going to the boards." A few participants that represented all three grade bands included how the students enjoyed the experience of using the markers and boards. T2 stated, "There's like dancing and carrying on and they just love being over there [at the boards] doing their work. They are so engaged in it. It makes math a little bit more likeable."

Growth Mindset. Statements were made by participants on the affective engagement of students with the use of VNPS. Participants perceived their students' feelings toward math improved following their implementation of VNPS. T35 stated, "Students displayed an increase in confidence as their peers provided motivation through collaboration." T13 reported, "The impact on student engagement is tremendous. Students look forward to 360 math. They are on task and involved to a greater degree, and usually they don't want to stop, even when the class time is over." T2 said, "All of my students beg to do it [work on the boards]. This is across the board from my struggling learners to the gifted learners." All 14 of the interviewed participants and many participant responses on the questionnaire shared an eagerness of the students wanting to complete mathematics problems at the boards and having the confidence to do it. T46 felt students are encouraged to take more risks of trying to solve a problem when they can see other student's work. T3 found students would take risks on challenging math problems:

> They went from backing off anytime they saw a challenge [problem] to feeling like they could take it on. And, I think that's because of the collaboration. I think immediately as soon as you put kids up on the walls [boards] and they can see each other's thinking, the collaboration comes naturally. Kids ask questions naturally. When you have other kids' thinking visible, you're opening up the door to allow for that communication through collaboration, which typically doesn't happen when you can't see somebody else's work. Now they are willing to take risks and they're willing to fail because they feel supported by their peers. The boards make it a collective math effort.

All 14 of the interviewed participants perceived most students had better attitudes, felt more confident, and felt it was okay to make mistakes when solving problems with the use of VNPS. The positive relationships built with the students, from the act of working together by helping one another, contributed to the perception of students building a growth mindset. T7 observed, "Students can instantly determine mistakes and seek clarification, which builds math confidence." T8 shared the success of one student:

> My lowest achieving students seem to have the greatest benefit [with VNPS]. Because there are a lot of times the low achieving students are self-conscious that they don't understand something, and they won't raise their hand for help. They won't ask a question. I was in the center of the room observing students and I noticed a student just standing at her dry erase board. She had a horrible experience in her previous math classes before she came to my class. She was just standing there, and she wasn't doing anything. So, I walked over to her very discreetly and realized the gaps that she had in mathematics. So, to me, the most powerful thing [of VNPS] is the engagement. She probably would have just sat in my classroom and I wouldn't have even been aware of her gaps in learning. I think [VNPS] changed her course of her self-confidence and helped her to put forth effort in other content areas too. She started seeing [progress]) and started getting some confidence. I think she has become a better student just because she happened to pass through a math class that had VNPS.

T4 voiced a similar experience with a student:

> It [VNPS] allows us to work with them [students] and help them and their confidence level is incredible to watch it grow. I got this email this year from a girl that I had two years ago. I had her for on-level math, and she was also in math literacy [a support course]. She came to our district in 8th grade and now she is in honors geometry this year and it just made me cry. I'm getting emotional thinking about it. She just emailed me to thank me and say what a great foundation she received in math. And, I really think

that's because she didn't have a choice to not be engaged [with VNPS]. I mean, it's amazing to me, I love it.

The word *confidence* was used by 16 participants to describe the students' growth mindset at the onset of using VNPS. T43 shared a statement eluded to by other participants, stating, "Students feel more confident when their steps or answers are similar to the rest of the students' boards." Other participants commented regarding students helping each other without judgment, students comparing their work to others through self-reflection and error analysis, and the perception that students felt better about being able to correct their mistakes quickly without being singled out. As T11 said, "They definitely are proud of their work." T11's students took pride in showing what they know on VNPS and the pride of sharing the space with their administration when they would come to visit the classroom. T5 claimed that parents spoke of their kids sharing about their math class at home for the first time in a very long time because of the boards. T10 suggested, "The boards took away things that kids are afraid to do in a math class, such as asking questions or being afraid to make a mistake because it can be erased, and they can start again."

Community of Learners. Participants used phrases in their responses such as social interaction, community effort, increase in collaboration, and students helping each other that supported the theme of community of learners when implementing VNPS. Every participant interviewed held the perception that VNPS enabled their students to work together more effectively and collaboratively. T1 shared about students' view of mistakes:

> They [students] think it is great for you to finish [math problems] first. They think you shouldn't make mistakes. Breaking those habits is something that math teachers, especially in elementary school, kind of struggle with. If you have students working next to each other [on VNPS] and one student is stuck and another student says let me help you, it's collaboration. We're helping each other learn, we're making sure that we're growing together. And, they kind of like it.

T2 stated, "The engagement is knowing they can walk around and talk to each other through a problem. It [VNPS] seemed to help the fact that it's okay if I don't know it." T3 said, "The boards allow for a collective math effort where we are working together. You have collaboration, communication, and excitement." T4 observed students encouraged each other and stated VNPS was a *game changer* in the classroom. The responses from eight of the interviewed participants described how they perceived their students appreciated the social interaction and the comfort of being able to rely on each other for help whether it be verbal or looking at each other's boards for hints or sharing their ideas on different ways to approach a problem. T13 explained how students visually compared each other's math work:

> I say to the students, okay, spin yourself 360 degrees and look at what other people have and see if you're on the same track as everyone else. And, as soon as they do that, there's always a few kids in the room that can spot those that are struggling. They leave their board and go over [to the student] and they're like look, you got all the way through right here

> and then you forgot to do this. They talk them through it and then they go back to their own board.

T1 responded regarding development of the student community:

> They [students] see each other like a whole community. They're able to feel comfortable talking to people who in the past they might not have spoken to or even made connections with. They see their room as a community of learners. They are able to give feedback to themselves [through self-evaluation] and to each other.

T12 liked the collaboration between students. T13 said, "I was very excited collaboration happens instantly with kids and kids are talking to each other. They help each other and there is more interest in the problem." T34 concurred, "They [students] are becoming much more aware of their work, correct or incorrect." T4 explained, "They help each other and it's just a camaraderie. The class becomes more like a family because we're all in it together." The responses from the participants of this study on teacher perception of the influence of VNPS on student engagement in mathematics classrooms indicated classroom teachers perceived VNPS to contribute to higher levels of on-task behavior, the development of a growth mindset, and the development of a community of learners.

Research Question 2

What are teacher perceptions of daily formative assessment and feedback for individual students using vertical non-permanent surfaces in 2nd-12th mathematics classrooms in a school district in the State of Georgia?

I reviewed the questions regarding formative assessment and VNPS from the questionnaire and the interviews. Descriptive responses from questions 12 and 15 from the questionnaire and questions two and five from the interviews were recorded and separated by elementary, middle, and high school participants. I reviewed the feedback questions from the questionnaire and the interviews. Descriptive responses from questions 13 and 15 from the questionnaire and questions three and five from the interviews were recorded and separated by elementary, middle, and high school participants. The common responses were coded and combined under each grade level and reduced to four themes.

Table 2

Codes on Formative Assessment and Feedback with VNPS Developed into Themes

CODES		
Elementary	Middle	High

Achievement increase Adjust instruction Assistance from peers Community of learners Daily assessment Differentiate Easy to collect Favorite time of class Fix errors instantly Frequency increase Group feedback Immediate Individual feedback Less punitive Meaningful On the fly Positive feedback Quick Self-assessment increase Timely View all work at once Understanding increase	Achievement increase Adjust instruction Assistance from peers Attentive Camaraderie Compare work w/peer Confidence increased Conversation increased Camaraderie Daily progress Differentiate Easy to collect Fix errors instantly Frequency increase Group feedback Individual feedback No technology issues Positive, helpful feedback Precise feedback Productive class time Quick Real-time See common misconceptions See gaps quicker Self-assessment increase Student ownership Shorter formatives daily Take more risks Tutoring time reduced Understanding increase View all work/processes	Achievement increase Ask for help Behavior improved Better questioning Compare work w/peer Daily Data increase Differentiate Easy to collect Efficient Fix errors instantly Frequency increase Immediate Individualized feedback Informal and formal Learn personalities faster Metacognition increase Mistakes decrease Narrow focus of needs No longer a struggle Positive environment Proud of work Productive class time Quick Real-time Self-assessment increase Social interaction/collaboration Take more risks Understanding increase Verbal increase
COMBINED CATEGORIES		
Achievement increase Adjust instruction Collaboration Easy to collect Fix errors instantly Immediate or instant Peer and teacher formative assessment and feedback Positive feedback Self-assessment increase		

Timely View all work at once
THEMES
Quick, Authentic Data and Feedback Deliberate Instruction Collaborative Interaction Growth in Understanding

Note. The first row of the table represents codes from the three grade bands. The second row of the table represents developed categories from the combined codes. The third row represents the emergence of four general themes from the three grade bands.

The descriptive words identified as codes were listed for each of the three grade bands from the questionnaire and the interviews. Each column of codes were alphabetized. Commonalities were noted for elementary, middle, and high school responses and were recorded under categories. From the categories listed with common responses from all three grade levels, four general themes emerged.

Quick Authentic Data and Feedback. Responses from all the participants revealed the perception that formative assessment via VNPS provided for the collection of immediate, real-time data. The reference to *quick, easy, and instant* was provided by 38 participants on the questionnaire. T1 pointed out, "I feel like it's more meaningful because I'm able to see it [student work] first hand and I'm able to see it really quickly." T2 shared, "It's definitely a lot faster than a ticket out the door, especially when you have to stop and grade it. VNPS is priceless in obtaining formative data, totally a game changer." T4 explained, "The frequency [of formative assessment] has increased ten-fold," supporting the interviewed participants' responses that frequency had increased, such as T5 saying formative assessment has increased *100%*. T3 compared VNPS to the traditional mathematic classroom setting of collecting formative assessment:

> So, it [formative assessment] happens daily now and that was next to impossible previously. In a classroom of 30 plus students, you can't formatively assess them daily and review it daily. Especially if you are departmentalized and you have 60 students that you are looking at every day. That's next to impossible. When you're doing it [formative assessment] in real-time, it's every day, it's individualized, really individualized where it wasn't before. Now you put the process of thinking up on the wall. It's giving me another level that I can assess, which has been incredible to see.

T13 mentioned she could have had a couple hundred formative assessments to grade every night, and it slips by the wayside, where VNPS was "fast, straight around the room where mistakes are caught very quickly." T11 similarly stated, "On the fly, you can get a real quick check on something." T4 contributed about misconceptions:

> One thing I just always disliked about math before, as I would go over things, I would think they would get it. They would go home and then they might practice it the wrong way. So, then you are stuck undoing something they learned the wrong way and having to correct it, which is inefficient to me.

T9 spoke of formative assessment being a struggle in high school:

> Oh, I would struggle with it before when students were at their desks and I probably rebelled against it [formative assessment] even though I knew it was really important. I struggled to find ways to help kids feel more comfortable with giving me feedback about their learning. When students are sitting down, you can't tell what they're doing. If it's in a teacher-centered classroom where all the desks are facing forward, I would struggle with it [formative assessment] because they don't want to hold up their fingers [to represent their understanding]. When students were up at the boards, I would get a quick idea of who needed the most help. I would have them check themselves and erase the correct ones and leave the ones that they got wrong up on the boards. It helped me as a teacher to really eliminate the stuff that I knew that they were fine at so I could home in on one singular problem they were having.

Seven participants in the study responded with comments about how VNPS has lessened the number of papers they take home to grade. T32 shared, "Feedback is so important in the learning process, and this [VNPS] reduces papers that need to be graded to provide feedback." T9 emphasized the reduction of papers:

> Because I can see more problems in real time, I'm able to give them a grade more frequently and quickly which doesn't seem like as much of a paper burden because they are getting the feedback they need in real time.

T10 perceived paper ticket out the door used as formative assessment did not adequately address misconceptions in real-time because they were referred to after the lesson was taught. They shared, "I don't have to collect papers and then have a stack of stuff to take home with me. I'm doing it [formative assessment] right then." They pointed out students would find out after the fact if they had a misconception or a common error and the students did not seem to learn from feedback after the fact. T13 referred to trying to observe the work of an entire classroom of students sitting at desks as "next to impossible." T14 agreed, stating they felt more comfortable formatively assessing with VNPS rather than paper and pencil as they were able to "correct any misconceptions before students left the room." T24 shared, "I can see 30 problems within minutes with VNPS where before I would only be able to look at one problem at a time when they [students] worked on paper at their desks." T26 said, "Students can be examined and questioned immediately in a non-threatening, unobtrusive manner that results in constructive learning." T36 agreed with the response, "I love using VNPS as quick checks throughout not only the week, but also the lesson." T32 said, "I use VNPS to assess for learning on a daily basis. I am able to address misconceptions before the summative assessment."

The immediate feedback with VNPS was noted by 100% of the study participants. Participants elaborated on how quick, instant, and more frequent feedback to students was with VNPS. Fourteen participants explicitly stated giving feedback was easier than in a traditional math classroom setting. T2 claimed, "I love the fact that I can be right there with feedback for so many kids instantly." T10 described, "I'm able to give feedback faster because anywhere that I'm in the room, I can see them. I don't have to walk over and look at their paper." T8 found you could discreetly provide students feedback in just a few seconds with VNPS. They shared how they could be working with a student at their board but look across the room and provide quick feedback to other students at the same time. T5 responded about feedback:

> I can say with all honesty, that I hardly gave feedback and it's now that I give feedback a lot and it may be choral feedback if I see everybody doing the same thing, or it may be individual. When I survey my students at the end of the year, that is the positive thing that they have to say is that I'm able to get to them quicker with instruction and feedback. I really hardly did it when I was in a traditional math classroom. The immediate feedback to the students is a game changer. The students feel that I am more available to them.

T3 explained their feedback to students happened daily with VNPS unlike before the use of the boards. Feedback was fast, positive, and immediate. The students knew right away how they were performing. T4 shared, "Using VNPS allows me to give feedback that is immediate and accurate. Without VNPS, there is a lag time between student response and teacher feedback." T44 determined feedback was immediate encouragement for hesitant students. T26 explained, "The impact of VNPS on the feedback given to students is highly valuable. Instant feedback combined with immediate ability to work the problem creates a win-win for the teacher and student." T23 agreed and stated, "VNPS reigns over traditional classrooms in that they provide a much quicker turn-around time with feedback." T18 confirmed the effects of feedback on misconceptions:

> Feedback is quick and in real-time, which is so important for students. I can give feedback to one student and observe other students responding to that same feedback. It is so important to give real time feedback while the

> students are working instead of waiting for them to spend 30 minutes solidifying a misconception. With the use of VNPS, I can see all my students work instead of a few students at a time.

Deliberate Instruction. Respondents mentioned the act of adjusting instruction, differentiating for learners, creating small groups, and observing the process of student thinking as positive outcomes of formative assessment with VNPS. T10 stated, “Naturally, it’s [VNPS] easier because you are doing it right then, which makes us feel better because we can change instruction right then.” T7 concluded about differentiation:

> The ability to differentiate on the spot with a VNPS mathematics classroom changes the way in which math is taught. You can literally meet the needs of your students instantly [with effective up-front planning]. VNPS allows students to work at the pace and level that is needed for success and allows teachers the instant snapshot that is necessary for student success and individual learning goals.

T5 agreed, “Grading in my head when the students are at the boards allows me to tell the students to go back to their desks and let’s drop back 10 and punt, so to speak, because I see some major issues.” T4 expanded on adjusting instruction:

> VNPS allows me to formative assess students much quicker, and more importantly, it allows me to make corrections or redirect the student before bad habits are learned. Whatever I feel like they need extra practice with, that opportunity to formally assess where they are and what they’re doing may change my instruction a bit for that day. If I see they need some

> reinforcement on something, which can guide my lesson for the day as well or just alter it.

T2 indicated using VNPS allowed for the visual identification for students who already understood the concept and determining how deep the instruction needed to go. T3 shared the formative assessment from VNPS gave them another level that they can assess. T3 stated, “It is incredible to see, as you can make your groups and give instruction to match wherever that child or group of children need help.” In agreement, T1 responded about small groups:

> I’m able to do a quick check to see if any student needs to be pulled for small group because they lack the conceptual understanding of what we’re doing. Or if they need to be pulled into a small group because of their math facts. So, now I like the formative assessment because it is meaningful and quick.

T44 stated, “After observing student work, teachers can reflect on a lesson and plan for upcoming lessons to fill knowledge gaps or provide extensions as necessary.” T3 summed up formative assessment for deliberate instruction:

> The use of VNPS has dramatically improved formative assessment in the classroom. I can collect authentic data on student understanding immediately after instruction and use that data to adjust whole group and small group instruction instantaneously. I have access to formative data each day and I am able to collect [these] data while also providing feedback and support in real-time. This has greatly improved my ability to identify specific student needs and plan for future learning opportunities of

students that meet those needs. I rely on my VNPS instruction and formative feedback daily when planning for and adjusting instruction.

Collaborative Interaction. Over 50% of the participants noted feedback was not only being given by teachers but also by students' peers following the implementation of VNPS. T9 spoke of giving verbal and written feedback on the boards. They mentioned having observed a student who solved a problem well going over to another student to help. T9 shared, "It gives two types of feedback. It tells the student the he did it correctly, but it also gives feedback to the other kid that was struggling, too." T1 reflected on student feedback, "It's authentic the way they give feedback from their perspective. It takes the focus off of the teacher as being the sole provider of the knowledge and makes us more of a facilitator." T9 perceived the students to be *more reflective and collaborative* with VNPS. T3 believed the *collaboration and communication* promoted students taking risks on solving problems.

T2 felt their students connected with collaboration when they responded:

> They love the feedback from their peers. They go to each other and say hey you know what could be wrong? How can I fix this? And, you know they've really gotten to where they love teaching each other and being taught by each other.

Along the same lines, T12 shared about feedback:

> I believe the learning process happens a little faster with the VNPS model because students get almost immediate feedback while working at the boards with a partner. Whether the feedback is from me or their partner,

> students tend to retain skills better. The experience is more meaningful than if they work alone at their desk.

T13 found students become confident in comparing their work with their peers' boards as a form of feedback. T13 gave students permission to "talk to each other and find the experts around the room so they don't have to wait and rely on me." T15 suggested students were more willing to ask for help after conferring with another student. T15 said, "If they got a different answer from their neighbor and they both thought they were right, they would ask for clarification on who was right." T24 allowed students who had the same misconception of a skill to work together as a group. T19 perceived students being able to view other students' work and observe their peers making the same mistake that they had, was a positive characteristic of VNPS of encouraging collaboration. T45 shared about collaborative discussions:

> Feedback with VNPS is more of a conversation or discussion rather than a grade on a paper. VNPS feedback is more welcomed and accepted by the student and the feedback is not only from the teacher, but from peers as well. Which brings it back to the team and collaborative aspect of learning with VNPS.

Growth in Understanding. The interviewed participants perceived their ability to see mistakes quickly and address students instantly with VNPS resulted in increased academic performance. T7 shared about academic performance:

> So, in turn, it would have to definitely impact their academic performance because they weren't making the same mistakes 10 times before they were

> getting the feedback needed. It's [formative assessment] more frequent because it's easier for me to instantly give that to them.

T9 noted about formative assessment with VNPS:

> I think it taps into the metacognition piece a lot more. It gets them thinking about their own thinking and it gets them to become more of an assessor of their own knowledge a lot more frequently than they would be if they were sitting at their desk. It gets them thinking in a more reflective way when they are standing at the boards.

T1 agreed and stated, "I think it's positively impacted performance, as students know what questions they need to ask." T3 stated their disappointment with not having the chance for their students to take a standardized assessment during spring of 2020:

> With these boards, we changed math. There is a distinct difference between how many of the kids were performing before we had the boards and after we had the boards. My struggling students were completing more work, making an effort, whereas before [VNPS], you wouldn't even get that effort. So, you did see an increase in academic performance. In my high achieving kids, I saw big growth in their ability. The explaining, the justifying grew incredibly. I saw a better academic performance, probably tied partially to their engagement in the work.

T6 thought it was hard to confirm growth in academic achievement without standardized assessments, but they stated, "A lot more students feel comfortable with the material and about doing the math." T10 discovered students were "proud of their workspace" [on the boards] and showed all their work when working a problem. They perceived the process of students showing their work and seeking feedback as evidence that students were performing better academically.

Four interview participants across all three grade bands, who have been implementing VNPS longer than most of the participants, shared an increase in assessment scores. T2 stated, “If you look at our data compared to the rest of the grade level, the kids are just rocking it, it’s amazing.” T5 shared results of state assessments:

> It [academic performance] has increased in all. I am a firm believer that it has increased my EOC [end of course] scores. As I implement [VNPS] year after year, my scores increase. My principal came down to my room last year and said that my on-level students’ mathematics scores went off the charts. He wanted to know why. I told him that I think it is the boards because I can formatively assess quicker. I can get to the issues quicker. He questioned “It’s all about these boards?” I answered absolutely.

T8 believed they saw a 10-20% boost in scores across the board. They stated it *was significant*. T8 shared about the data: “You can see it versus not having the boards. I don’t know if it is the boards for sure, but it sure can’t be hurting it [academic performance], you know.” T13 agreed, stating, “I’m getting more data and the [data] ultimately [do] show higher scores on testing, quizzes and any higher-level assessments we are taking. I do see [positive academic performance] regardless of their level, I have seen growth with it.”

Over 75% of participants mentioned correcting student errors, fixing errors instantly, and clarifying misconceptions as the focus of their feedback.

Participant perceptions were that VNPS allowed for them and their students to see mistakes quickly and provide positive feedback and allowed for productive class time. Many participants liked how the use of VNPS allowed them to see all student work at once that resulted in general or individualized feedback. A popular comment by participants was how students took risks in completing more challenging problems due to the feedback that was being received. T4 shared about the constant positive feedback with her students:

> The boards allowed me to tell them what they were doing right and what they were doing wrong. I used to just walk around and look at their papers on their desk searching for something [to say]. With the boards, I can say, awesome job on that first step, I love the way you started. Now let's take a look at what you did in the second step. Let's rethink that. It [the boards] gave an opportunity for me to establish a positive relationship.

T3 viewed students reversing their fear of a "challenge to feeling like they could take it on" with the use of VNPS. T3 shared about the perseverance of students:

> You can give instant feedback on the process of solving problems, like that is incredible. You could never do that before. You see students taking on more challenges. More often they are engaging in thinking that they weren't touching before, just out of fear, when you're giving them that positive reinforcement when they're trying something new. They are way more likely to keep going. I think you're seeing a positive academic growth because I can pinpoint when the students are making a mistake and give them guidance. By responding with a question as feedback, you put the ownership of learning on the kids.

T5 found the students would confidently refer to the feedback they received with VNPS when they were taking a paper and pencil assessment. They found the students "are quicker to get their mistakes because of what I have said to them when they've been at their board." T6 liked that she could give helpful feedback since she could see all the steps students listed when solving a problem. T7 shared about student eagerness:

> Most students just want to know if they are correct or not in their thinking. So, having the ability to quickly determine that along with correcting any mistake if needed makes students eager for more learning. My on-level and co-taught students did better than my advanced kids for sure. They were way more engaged than when they were sitting at a desk and they worked better at the boards with more confidence. The students that typically didn't do work, they asked questions and were more engaged.

T10 perceived class time practice was much more efficient with feedback, and students made less errors on assessments. T10 noted that struggling students were making progress:

> I'm catching it [mistakes] right as they are doing it. It [learned content] is sticking with them longer, so the academic piece is going to be better when I'm grading them more frequently and giving them that continual feedback of what's wrong. The students are building their confidence and participating.

T11 agreed with T12 in the focus group interview when T12 said, "Feedback is definitely more frequent, more precise, and more individualized." T14 added the feedback was more than saying the answer is correct or incorrect, but more of how the students made the mistake in the process. T11 noted the students wanted the feedback especially if the teacher didn't notice or have time to view their work on their board, as the students were *proud of their work*. T29 explained, "Success allows them to feel more powerful in the content and this is what VNPS promotes." T28 shared their perception of student progress:

> I think the impact is very positive for students as I am able to help them identify missteps and to guide them in going back and correcting work as it occurs. Less procedural errors to try to fix later after they have become ingrained. It also allows me to individually explain the why with the how. Those that have got it can move on to more challenging problems or tasks. They are more confident and more willing to be persistent in thinking through a challenge without immediately calling for help.

T17 stated their thoughts about feedback and student progress:

> Feedback is the bread and butter of VNPS. I was able to give feedback much more productively than in a traditional setting. Students felt better over-all because they could readjust and understand misconceptions without practicing incorrectly for a given time.

T9 surmised, "The students are more willing to try and work harder because they feel like there isn't really a floor or ceiling on their success." The data derived from participant responses regarding the perceived impact of VNPS on formative assessment and feedback were consistently aligned to each question on the questionnaire and interview protocol. All participants agreed the increase in frequency of formative assessment and feedback was beneficial to instruction and student engagement.

Research Question 3

What are teacher perceptions of the lesson structure of *360 Degree Math* when implementing vertical non-permanent surfaces in 2nd-12th mathematics classrooms in a school district in the State of Georgia?

I reviewed the responses of participants regarding *360 Degree Math* and VNPS from the questionnaire and the interviews. Of the participants, 36 had attended at least one professional learning with Kavanaugh in January 2020 or July 2020. Due to COVID-19, participants only had the opportunity to implement the lesson structure with students in the classroom setting from January 2020 to March 2020. A total of 21 participants implemented parts of the lesson structure during this time. Descriptive responses from question 14 from the questionnaire and question four from the interviews were recorded on an Excel document. I reviewed the responses and coded the text. The codes were combined and represented by categories, then reduced to two general themes, which were *student-focused* and *structured routine* (see Table 3).

Table 3

Codes on 360 Degree Math with Vertical Non-Permanent Surfaces Developed into Themes

CODES	
Descriptions	Lesson Structure
Achievement increase Atmosphere-positive, lively, exciting, energy Build relationships Chunk learning Classroom management	Exchange Rewind Progress Bar Micro-lecture

Clips/3 markers Confidence booster Different levels of learning Effective Erase problems-reinforcement Individual work time Spiral instruction Standing at the boards more Student-focused Students engaged Students challenged Workshop	
COMBINED CATEGORIES	
Energetic Chunking micro-lecture Differentiation Spiral instruction Student-focused	
THEMES	
Student-Focused Engagement Structured Routine	

Note. The first row of the table represents codes from the *360 Degree Math* implementation. The second row of the table represents combined categories from the codes. The third row represents the emergence of two general themes.

All 36 participants who attended the professional learning responded they would likely or very likely implement the lesson structure of *360 Degree Math* with VNPS. The 21 participants who implemented the lesson structure or parts of the lesson structure for the short period of three months shared their perception of how it enhanced VNPS through *student-focused engagement* and a *routine for instruction* with their mathematics lessons.

Student-Focused Engagement. Participants shared descriptions of building relationships, positive atmosphere, academic challenge through differentiation, different levels of learning, confidence booster, and engaged as their perception of the impact of *360 Degree Math* with VNPS that led to the theme of student-focused engagement. Nine participants responded regarding their perception of student engagement with the lesson structure. T26 said, “The teaching strategies were implemented into my lessons, which kept my students engaged and challenged.” T4 stated it impacted their classroom atmosphere:

> I would have the music going. They would know to do their progress bar. I would have 10 problems timed for the duration of the music. It was lively. It was positive. It was exciting. The energy was phenomenal too, so that was probably the biggest takeaway that I got [from *360 Degree Math*].

T27 shared, “The structure keeps learners engaged and wanting to do the work. Building a relationship with students with the greeting and game review format helps learners to be more comfortable with math and making mistakes.” T16 exclaimed about student engagement:

> I think VNPS and the lesson structure of *360 Degree Math* had a tremendous impact on the instruction in my classroom. Students are engaged and always excited to be at the boards. They have developed confidence in their math skills and have learned that it is okay to not only make mistakes, but to rely on each other if they are stuck.

Six participants stated the lesson format was a confidence booster for students. Seven participants mentioned the differentiation within the lesson structure of *360 Degree Math* as important for students to choose the level of question they wanted to work on. The participants liked that the students were able to choose from different levels of questions to work on and many students would try the challenge problems that they would not have attempted before the implementation of VNPS.

Structured Routine. Within the *360 Degree Math* lesson structure, *The Exchange* was the greeting of the student and teacher at the classroom door with some type of handshake or fist bump. The teacher would provide a positive comment to the student to set mood for the day. T37 liked the acknowledgement of students with, "I greet the students at the door to show them that they are seen by the teacher." T9 shared the greeting at the door was good, but the handshake or fist bump was difficult for Them. T9 expanded their response about the greeting:

> I do think that they [the students] appreciate the presence, and I think starting your day off strong with the presence like that was really good because VNPS really revolves around interaction between the students with the creation of a group mentality. I don't think I am going to do that [handshake or fist bump] as it felt awkward to me, but I will find out another way to do it.

The next step, referred to as *The Rewind* within the *360 Degree Math* lesson structure, consisted of a warm up of about 10 review problems for the students to complete at their own pace. The classroom was energized with music and the teacher called out to each individual student with feedback of their progress. *The Rewind* was mentioned by seven participants as an integral part of the lesson structure to build participation of students and a growth mindset by solving problems that were reachable by students. T3 liked the spiral review aspect of the work with the response:

> The whole review thing, like wow, spiraling instruction. Because you always wonder, well how am I going to touch back on stuff? It didn't interfere with my instructional time and I didn't feel like I was losing something. I greatly enjoyed the time for the rewind as it allowed me to see what knowledge students have not retained and it gets the kids ready to learn.

T13 noted easy problems were needed during *The Rewind* for engagement and as a confidence booster. Four participants made use of the magnetic clips to post work at the boards for students for easy access to the problems and it eliminated the students looking back and forth between their personal board the board in the front of the room.

The Micro-Lecture consisted of the mini-lesson at the start of each lesson where the students immediately went to the boards to practice the newly learned material. Seven participants liked *The Micro-lecture* for the short instruction time and the chunking of instruction with more practice at the boards. T7 exclaimed, "Oh, it changed it a lot. It made me stick to 10 minutes for my lecture. I would have a kid time me when I was instructing." T10 responded, "A big takeaway that I have implemented in my class is the short chunks of direct instruction and having the students get up immediately to start utilizing what they have learned at the boards." T18 explained they adapted *The Micro-lecture* to fit their classroom needs, as they felt it was important for students to still have time to work with manipulatives during instruction.

Seven participants mentioned the chunking of levels of learning during *The Practice* as upping the differentiation in the classroom. T14 liked that the students could choose which level they wanted to practice. T14 indicated they appreciated the individual worktime at the close of the lesson. T27 mentioned the *360 Degree Math* lesson structure "It allows for math instruction from bell to bell!" T18 replied, "I think the lesson structure provides the optimal opportunity for students to feel encouraged, review previous standards, learn a new concept, and engage in the learning environment." T6 liked VNPS from the start, but after they experienced the *360 Degree Math* lesson structure, T6 felt like, "I have been able to really improve my instruction in the classroom." Over 90% of the participants who implemented the *360 Degree Math* lesson structure plan on continuing with the lesson components for a structured routine and student focus with VNPS.

Summary of Results

I presented the teacher perceptions of the impact of VNPS through the lens of the research questions posed in this multi-site, multi-case, qualitative analysis. Data were collected from participants teaching in 2nd-12th grade mathematics classrooms by means of an electronic questionnaire, virtual individual semi-structured interviews, and an virtual focus-group interview during August and September 2020. The questionnaire responses were exported into an Excel document, and the interviews were transcribed by me and member checked by participants. The interview responses were organized into the same Excel document under a different tab for reference. The data were separated by each question on the questionnaire and each question on the interview protocol, then assigned to elementary, middle, or high school. Descriptive words were highlighted in all the data for each question and then combined to represent each research question for each grade band. The codes were combined and narrowed, then condensed into broad themes for each question. Participant responses were reported for each research question for contextual understanding.

The teachers' perceptions of the impact of VNPS on engagement of students included behavioral, affective, and cognitive responses. The themes that emerged from the coding of descriptive words and phrases were on-task, growth mindset, and community of learners. The teachers' perceptions of the impact of VNPS on the formative assessment and feedback of students resulted in the themes of quick, authentic data and feedback, deliberate instruction, growth in understanding, collaborative interaction, and student ownership. The participant responses regarding the perception of the implementation of the lesson structure of *360 Degree Math* with VNPS emerged the two themes of student-focused engagement and structured routine. The analysis of the responses contributing to the research questions provided the basis for the conclusions and implications discussed in Chapter V.

Chapter V: Conclusions and Recommendations

Teachers' perceptions of the impact of VNPS in mathematics classrooms were the focus of this study, as a need was identified to increase student engagement, formative assessment, and feedback for comprehension of math concepts to increase academic achievement. With the increase of a STEM focus in society, an overhaul of the traditional mathematics classroom was needed to increase the engagement of students for preparation of these jobs (Lefkowitz, 2018). The study took place in a school district in the State of Georgia in mathematics classrooms in 2nd-12th grades. Chapters I and II of this multi-case, qualitative study identified the problem, the gap in the research through the literature review, the significance of the study, and the relationship to the conceptual frameworks of Teacher Noticing, Mathematics Teacher Knowledge, and Social Learning Theory. The three research questions were presented to find answers based upon the data. Chapter III focused on the methodology of the study. This included the research design, participants of the study, the data collection methods, and the methods for analysis. Multiple data points collected consisted of an electronic questionnaire, individual virtual interviews, and a virtual focus group interview. The results of the data were organized in Chapter IV, where I reported the prominent themes that emerged from data collection that supported the research questions. A summary of the findings, conclusions, implications for practice and further research have been included in this chapter with a statement on the impact of the research.

Conclusions of the Study

The data collected from this multi-case, qualitative study answered the three research questions regarding teachers' perceptions of the impact of VNPS in mathematics classrooms. The electronic questionnaire, virtual individual interviews, and virtual focus group interview participant responses provided insight to commonalities among grade bands and multiple schools with the implementation of VNPS. The conclusions of this research study were based upon the findings, which could impact the setting and environment of future mathematics classrooms. The teachers' perceptions of the impact of VNPS on engagement, formative assessment, feedback, and *360 Degree Math* with students provided insight on the mathematics learning of the current educational environment of a technology-driven society. A simple construction of the current mathematics classroom with dry-erase boards attached to the walls provided teachers with the ability to increase the engagement of their students and provide immediate, real-time formative assessment and feedback to students on their current progress from a live teacher rather than artificial intelligence. The relationships built by teachers with students using VNPS impacted the growth mindset of students and increased the speed at which students progressed towards mastery of their mathematics learning.

The teachers' perceptions of the implementation of VNPS in mathematics classrooms in elementary, middle, and high schools had a profound impact on the engagement of students. Engagement was substantiated across all grade levels. *Studenting* behaviors, as described by the research of Liljedahl and Allan (2013), had decreased or subsided altogether. Teachers' perceptions were students were more accountable due to not being able to hide from or avoid the mathematics. Teachers perceived there was an overall increase in engagement with very few students preferring to not make use of the boards. Participants speculated the few students who chose not to participate may have done so due to their low confidence of math understanding and the potential anxiety of displaying their work publicly at the boards. The teachers' perceptions included an overwhelming response to increased engagement with VNPS contributed to students' on-task behavior, the development of a growth mindset, and the collaborative nature of a community of learners. The teachers' responses supported the research by Berg (2011), Liljedahl (2016), and Reinholz (2018) regarding the engagement of students who used dry erase boards to practice mathematics work.

The positive perceptions of the teachers were the use of VNPS for the visual formative assessment, as it resulted in immediate feedback to students and increased engagement. Including the perceptions of their students, the teachers perceived the act of students standing at the boards as positive engagement, as it interrupted the act of sitting at the desks for long periods during the school day. The teachers perceived an increase in student participation based upon the positive environment of collaboration with VNPS. The reported teacher responses regarding the action of students collaborating through visually sharing and comparing their mathematics work supported Marshman and Brown's (2014) research on collective argumentation for engagement. Teachers recognized the social activity of students observing another student's work as a higher form of critical thinking of error analysis that engaged students, which supports Bandura's (1977) Social Learning Theory. Based on the teachers' perceptions, students enjoyed the experience; they looked forward to class, and a growth in confidence was observed that resulted in the increased engagement.

The teachers' perceptions of the influence of VNPS on formative assessment in mathematics classrooms in elementary, middle, and high schools was powerful. Teachers reported the ability to visually observe all students' mathematics processes, and answers on VNPS increased the frequency of formative assessment and allowed for the immediate adjustment of instruction. The conceptual framework of MKT provided the foundation for teachers to be able to formatively assess students in real-time and determine students' understanding of the mathematics concepts taught and differentiate for students' needs. Teachers perceived they were no longer limited by formatively assessing only a few students in real-time but were instead able to gauge the understanding of all students concurrently when at the boards. The teachers felt VNPS was more effective for daily formative assessment versus weekly quizzes or summative assessments because VNPS made it possible to determine the need for real-time instructional change or the need to adapt future instruction for their students, which was highlighted in prior research regarding effective formative assessments (Black & Wiliam, 1998; Hanover Research, 2014; Hattie, 2012; Sancho-Vinuesa et al., 2013; Shirvani, 2009). The immediacy of formative assessment was perceived by teachers as authentic and meaningful data that resulted in deliberate instruction for growth in student understanding.

Teachers shared they no longer take home incredible amounts of student work to assess after instruction has occurred. Instead, students were quickly assessed in real-time because VNPS allowed teachers to see all students' work and respond with an instant correction of any misconceptions or an issued challenge for students who were ready. The teachers shared formative assessment conversations occurred between both the teacher and students as well as between students themselves, which was supported as a best practice in prior research (Ruiz-Primo & Furtak, 2006). The teachers perceived VNPS made it possible for students to receive information in the moment related to the progress of their conceptual understanding of math, which resulted in deeper understanding of the content (Chappuis & Stiggins, 2002). Teachers shared conducting formative assessment of students had improved tremendously, as it had been cited as a general weakness in the traditional mathematics classroom (Klute et al., 2017).

The teachers' perceptions of the impact of VNPS on feedback to students in mathematics classrooms in elementary, middle, and high schools were positive. The teachers perceived the use of VNPS resulted in more frequent, positive feedback, which was easy to deliver, timely, and resulted in the reduction of misconceptions or errors. The teachers also shared the students were engaged with the feedback through collaborative interaction. The teachers found the delivery of the feedback was quick and effortless with VNPS. Group feedback was common, but many teachers stated individual feedback was the most productive for increased understanding (Kearney et al., 2013). Teachers perceived feedback was no longer a struggle to provide, a common problem cited in previous research, and instead contributed to more meaningful conversations with all students (Van Petegem et al., 2008). VNPS allowed teachers the ability to quickly see student mistakes and address them immediately. The act of the teachers incorporating the conceptual framework of teacher *noticing* with VNPS resulted in specific, precise feedback to students by responding to the actions and discourse of students in real-time, which reduced the number of errors and misconceptions before it was established as a learned understanding. Feedback was not only given by the teacher, but participants also shared it was easily enacted between the students as well. The teachers perceived the daily feedback possible through VNPS affected positive progress in mathematics understanding.

The teachers' perceptions of the impact of VNPS with the *360 Degree Math* lesson structure was positive. The structure of the routine was accepted by the teachers as it was relatable to already established practices. There were three practices of high interest to the teachers in the study with application of the lesson structure. The teachers liked the first practice of *The Rewind*, as it was effective in promoting an engaging environment where students built their confidence in mathematic practice and worked at their own pace on multiple problems. The teachers perceived the process of checking off correct work on a progress bar and erasing completed, correct problems promoted a growth mindset in students. The spiral review of previously learned concepts provided to students assisted teachers in understanding what misconceptions may still need to be addressed. *The Micro-Lecture* impacted the teachers, as it reduced the amount of time spent lecturing. The *chunking* of lessons was reinforced and reflected upon by many of the teachers, which resulted in students spending more time on practice at the boards. The third effective practice was the leveling of practice problems for the learned lesson. Teachers perceived the student choice of low, medium, or high challenge problems encouraged students to step out of their comfort zone and take risks.

The impact of VNPS increased student engagement and increased formative assessment with feedback to students. The professional learning of the lesson structure of *360 Degree Math* enhanced the effectiveness of the implementation of the boards. The perceptions of the teachers who implemented VNPS within their mathematics instruction was VNPS trumped the traditional mathematics classroom design consisting of desks in rows, for engagement, formative assessment and feedback, which supported the research of Liljedahl (2016). The purpose of this multi-site, multi-case, qualitative study was to examine teachers' perceptions of the use of VNPS for student engagement and mathematics learning from daily formative assessment and student feedback, and the use of the lesson structure *360 Degree Math* in 2nd-12th grade classrooms in one school district in the State of Georgia. The teachers' perceptions of the use of VNPS from this study included an increased engagement of students, increased formative assessment, and increased feedback for students and a positive enhancement to routine in instruction with the *360 Degree Math* lesson structure.

Implications for Practice

The practical implications of the results of the research on teachers' perceptions of the impact of VNPS in mathematics classrooms is to reconsider the setting of a traditional mathematics classroom of desks in rows. VNPS allowed for the teachers to observe all the students' work at the same time as the students were actively engaged and on-task. The visual of all the students' work encouraged collaboration, accountability, and the growth in student confidence. With the students standing and working at the boards, the teachers perceived VNPS positively impacted student engagement, the frequency and authenticity of formative assessment and feedback, and resulted in improved understanding of mathematic concepts. The increased understanding of mathematic concepts would ultimately impact the results on standardized assessments.

There are two practical implications for this study. The first is the remodeling of the traditional mathematics classroom to include VNPS. The installation of VNPS does not require an update year after year. School districts should consider future construction of mathematics classrooms to include VNPS. Teachers shared that the installation of shower board material from local home improvement stores could be substituted as a dry-erase surface. In lieu of dry-erase surfaces, windows in the classroom can also be useful. Another option suggested from teachers was the use of durable lamination of large chart paper.

The second implication is the need for professional learning for teachers who have VNPS installed in their classrooms. The focus of the professional learning should be effective ways of incorporating VNPS into the classroom instruction. This would include any of the following: discourse with students, formative assessment techniques, effective feedback, classroom management, collaboration and growth mindset, and the *360 Degree Math* lesson structure. The conceptual frameworks of Teacher Noticing and Mathematics Knowledge for Teaching should be a focus for professional learning for teachers, as they are the foundation for formative assessment and feedback from teachers.

Recommendations for Further Research

The gap in the research about VNPS and *360 Degree Math* leaves further researchers with a wide range of direction for future research. Participants from the elementary level shared more responses of students' engagement and growth mindset, whereas the secondary level of middle and high school had a small number of students who were disengaged or had anxiety standing at the boards. New research should include the comparison of students' perceptions on the growth mindset and engagement in mathematics with the use of VNPS in different grade levels. This should include the use of *360 Degree Math* as a lesson structure for support of engagement and building a growth mindset.

Further possibilities for VNPS research with the use of a larger sample size or the use of several school districts could be the comparison of math classrooms that implemented *360 Degree Math* versus those math classrooms that did not use the lesson structure focusing on the view of teachers' perceptions, student achievement, or students' perceptions. Another comparison should include classrooms with VNPS vs. those without VNPS focusing on student achievement, student perceptions, teachers' perceptions, or the frequency of formative assessment and feedback. With the gap in research of VNPS and *360 Degree Math*, there is a long list of research possibilities.

The findings from this research study included a wide variety of skilled 2nd-12th grade teachers who have implemented VNPS from three months to five years, with 70% of the teachers having implemented it for over a year. The implementation of VNPS should be studied in a different region to examine increased engagement of students, and increased implementation of formative assessment and feedback to students with minimal professional learning on how to effectively use the boards in instruction. The implementation of the study of *360 Degree Math* with the use of VNPS if studied in a different region would be the positive perceptions of the lesson structure with participants gravitating to *The*

Rewind, *The Micro-lecture*, and *The Practice* with leveled questions to enhance VNPS.

Another area of interest described by the interviewed participants was that of student achievement. Future research should compare student achievement with the implementation of VNPS to those classrooms without VNPS. Future studies with VNPS should include research on student achievement of subgroups such as special education, English as a second language, gifted students, and Title 1 students.

At the onset of data collection for VNPS with participants, the school district had changed the direction for instruction for students from in-person to virtual instruction due to the interruption of COVID-19. Participants wanted to continue to incorporate the strategy of VNPS in their virtual instruction. The interviewed participants stated how they missed their students working at the boards in their classrooms. Participants received professional learning for *360 Degree Math* with an exploration of how to mimic seeing all the students work at one time virtually. Participants experimented with applications such as whiteboard.fi, Desmos whiteboard, Nearpod, GoFormative, and Classkick for viability of VNPS implementation virtually. The application of VNPS in the virtual classroom should be the foci for further studies. A study on the impact of simulating VNPS virtually in comparison to VNPS with in-person teaching should be completed.

For teachers to be able to make effective use of the instant formative assessment of students with VNPS, they had to institute the conceptual frameworks of teacher *noticing* and mathematics knowledge for teaching. The background knowledge of mathematics content and pedagogy provided the means to analyze formative assessments to recognize when and how to provide feedback. A future study should be completed on the impact of VNPS with sustained professional learning for teachers on teacher *noticing* and mathematics knowledge for teaching.

Conclusion of the Study

The intent of this study was to investigate the teachers' perceptions of the impact of VNPS in mathematics classrooms. The impact of VNPS on student engagement, formative assessment of students, feedback to students and the use of the *360 Degree Math* lesson structure was the focus of the research questions. By disrupting the pattern of a traditional mathematics classroom featuring rows of desks and replacing them with VNPS, math teachers from the elementary, middle, and high school levels perceived they had been provided the opportunity to promote higher levels of student engagement with immediate real-time feedback from quick daily formative assessments. Teachers within this study stated they will never go back instructing with a traditional mathematics classroom. One hundred percent of the teachers in this study emphasized they will continue with VNPS for mathematics instruction. Based upon the findings of this study, the implementation of VNPS in mathematics classrooms would benefit student engagement of mathematics concepts by allowing for instant formative assessment for teachers and immediate feedback for students, which would promote an increase in mathematics understanding and ultimately student achievement.

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Appendix A

Vertical Non-Permanent Surfaces and 360 Degree Math Questionnaire

Questionnaire

Demographics/Information

1) Grade level/course taught: K, 1, 2, 3, 4, 5, 6, 7, 8, Algebra I, Geometry, Algebra II, Precalculus, Other
2) Number of years as a teacher: 0-5, 6-10, 11-15, 16-20, 20+
3) Level of Highest Degree: Bachelors, Masters, Specialist, Doctorate
4) Attended professional learning on general VNPS: yes/no
5) Attended professional learning on the structure of 360 Degree Math: yes/no
6) Classroom implementation of VNPS: 0-6 months, 6 months-1 year, 1-2 years, 2-3 years, 3+ years
7) Classroom implementation of 360 Degree Math lesson structure: 0-6 months, 6-12 months.

Implementation

8) On a scale of 1-5, what is the likelihood that you will continue to use VNPS regularly in classroom instruction?
    a. 1-very unlikely, 2-unlikely, 3-neither likely nor unlikely, 4-likely, 5-very likely
9) On a scale of 1-5, what is the likelihood that you will continue to implement the structure of 360 Degree Math regularly in classroom instruction? Including NA.
    a. 1-very unlikely, 2-unlikely, 3-neither likely or unlikely, 4-likely, 5-very likely
10) Which classroom instructional model do you prefer, VNPS or a traditional math classroom of desks and rows, and why? What are the benefits of the model you selected?
    a. Open-ended
11) What is your perception of the impact of VNPS on student engagement (for example: affective-emotional; cognitive-mental effort; and behavioral-observable actions by a student)?
    a. Open-ended
12) What is your perception of the impact of VNPS on formatively assessing students (the act of collecting information from the student before, during, or after instruction for use in improving student performance on the learning goals (the knowledge and skills of the standards that provide information for the teacher for their planning and deliver of clear lessons and assignments)?
    a. Open-ended
13) What is your perception of the impact of VNPS on the feedback given to students (information that is communicated to the student with intent to

change thinking or behavior to improve learning processes and outcomes that provide students with information they need to understand where they are in their learning and what the next steps are)?

    a. Open-ended

14) What is your perception of the impact of VNPS and Sean Kavanaugh's lesson structure of 360 Degree Math (if applicable) on the instruction in your classroom?

    a. Open-ended

15) Is there anything else that you would like to share regarding the impact of VNPS and/or the lesson structure of 360 Degree Math with your students and mathematics instruction (student performance, etc.)?

    a. Open-ended

Appendix B

Vertical Non-Permanent Surfaces and 360 Degree Math Interview Protocol

Interview Protocol

Candidate Name: Michelle Mikes
Date of Interview:
Time Interview Began:
Time Interview Concluded:
Participant Pseudonym:
Participant grade level:
Participant years teaching:
Participant advanced degrees:
Participant time implementing VNPS:
Participant time implementing 360 Degree Math lesson structure:

Researcher: Thank you for being willing to participate in this study. My name is Michelle Mikes and I am conducting this research for my Doctoral Dissertation. This interview should take about 20-30 minutes. This interview will focus on your perceptions of the implementation of 360 math classrooms or VNPS and/or 360 Degree Math lesson structure, should you use it. Your responses will remain confidential and your identity will remain anonymous. Do you mind if I record our conversation?

Researcher: You will be provided a printed copy of the transcript of this interview to provide you with the opportunity to check for accuracy and correct any information. You may end the interview at any time. Just tell me you want to stop. Do you understand everything so far?

Researcher: Do you have any questions?

Researcher: May we begin?

Researcher: Engagement, feedback and formative assessments are hot topics in mathematics. The school district has begun the implementation of 360 math classrooms or VNPS (vertical dry-erase boards) to address these topics. I am gathering data from the 360 math classroom or VNPS teachers as you have first-hand knowledge of the implementation. Included are questions regarding the 360 Degree Math lesson structure for those that attended professional learning and implemented the lesson structure.

Participant Questions

1. How do you believe the implementation of the 360 math classroom or VNPS impacted the engagement of your students in your math classes?

2. How do you believe the implementation of the 360 Math Classroom/VNPS impacted the frequency and manner in which you formatively assess your students?
    a. Can you tell me how formative assessment through VNPS has impacted student academic performance?

3. How do you believe the implementation of the 360 Math Classroom/VNPS impacted the frequency and manner of student feedback that you give?
    a. Can you tell me how student feedback through VNPS has impacted student academic performance?

4. Have you attended a 360 Degree Math instruction professional Learning? (If not, proceed to #5). How has the 360 Degree Math strategy changed your instruction?

5. What would you like to add regarding 360 Math Classrooms/VNPS that we have not discussed?

Researcher: Thank you for taking your personal time in assisting me with understanding the implementation of 360 Math Classrooms/VNPS and 360 Degree Math instruction.

Appendix C

Consent Form

Consent Form

Dear teacher,

As a student of the Ed.D. program in the Carter and Moyers School of Education at Lincoln Memorial University, I, Michelle Mikes, am currently collecting data related to vertical non-permanent surfaces (VNPS), otherwise known as 360 Math Classroom. The purpose of the research is to gain an understanding of the teacher perception of the impact of VNPS on mathematics instruction.

I am requesting your participation, which will involve completing a virtual questionnaire about VNPS and impact on your instruction. Completing the survey should take approximately 15 minutes. Participants will be asked if they would like to participate in a voluntary interview on the survey.

Your participation in this study is completely voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. Furthermore, not participating or withdrawing will not adversely affect your relationship with anyone at Lincoln Memorial University, your school district, or your local school. If at any time you discontinue the survey, your results will be discarded. Your responses will be kept strictly confidential, and data will be stored in secure computer files and secure storage location for paper copies. Any report of this research that is made available to the public will not include your name or any other individual information by which you could be identified.

This study is considered a human research project; however, the risk to you for being involved is minimal.

If you have any questions concerning the research study or want a copy or summary of this study's results, please contact Michelle Mikes at PHONE or michelle.mikes@lmunet.edu.

This research has been approved the Lincoln Memorial University's Institutional Review Board and the School District research department. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you may contact Dr. Kay Paris, Chair of the Human Subjects Committee, Institutional Review Board at 423-869-6834. Additional contact information is available at www.lmunet.edu/administration/office-of-research-grants-and-sponsored-programs-orgsp/institutional-review-board-irb.

I have read the above information and consent form, and I consent that I am over 18 years of age and agree to participate in this study. By clicking on the link to SurveyMonkey, I am confirming my consent.

Thank you for your participation.

Michelle Mikes, LMU Doctoral Candidate